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The Cost of Water Supply and Water Utility Management
Volume II

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A study of 12 selected water utilities was undertaken to determine the economics of water delivery. Data were collected from at least one Class A water utility (revenues greater than $500,000/year) in each of the U.S. Environmental Protection Agency's 10 regions. These data are summarized in two volumes. Volume II contains the basic data from each of the 12 utilities studied. Services of each utility were divided into five functional areas common to all water supply delivery systems - support services, acquisition, treatment or purification, distribution and power and pumping. These categories provided a common basis for collecting and comparing data. Costs were categorized as operating or capital expenditures.

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Volume II

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay among its components require a concentrated and integrated attack on the problem.

Research and development is that first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems (1) to prevent, treat, and manage wastewater, solid and hazardous waste, and pollutant discharges from municipal and community sources, (2) to preserve and treat public drinking water supplies, and (3) to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is a product of that research and is a most vital communications link between the researcher and user community.

The Safe Drinking Water Act of 1974 establishes primary, health-related standards and secondary, aesthetic-related but nonenforceable guidelines for drinking water supplies. These standards will bring about fundamental changes in the way water is handled before it is delivered to the consumer. Many of these changes will have an economic impact on the affected water utilities. This report provides detailed information on the current costs of water supply for 12 selected water utilities. In addition to providing information on the individual supplies, data are aggregated to provide projections of the relative impact of various strategies that might be undertaken to satisfy the Act's requirements. These data and associated analyses are presented in two volumes. Volume I is a summary of selected data from the study together with its analysis. Volume II contains detailed, in-depth information for each utility studied.

Francis T. Mayo
Director
Municipal Environmental Research Laboratory

ABSTRACT

A study of 12 selected water utilities was undertaken to determine the economics of water delivery. Data were collected from at least one Class A water utility (revenues greater than $500,000/year) in each of the U. S. Environmental Protection Agency's 10 regions. Volume I provides summary information and in-depth analyses of five of the utilities studied. All the utilities are analyzed in aggregate, and factors affecting the cost of water supply are examined. Also provided is an evaluation of the hypothetical impact of the Safe Drinking Water Act in 1980.

Volume II contains the basic data from each of the 12 utilities studied. Services of each utility were divided into three functional areas common to all water supply delivery systems--acquisition, treatment or purification, and distribution. These areas provided a common basis for collecting and comparing data. Costs were categorized either as operating or as capital expenditures.

This report was submitted in fulfillment of Contract No. 68-03-2071 by ACT Systems, Inc., under the sponsorship of the U. S, Environmental Protection Agency. This report covers the period June 20, 1974 to March 20, 1976.

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ABBREVIATIONS AND DEFINITIONS

Cost -- expense of water production
CPI -- Consumer price index
Maximum day/maximum hour -- maximum day flow for the year in MGD/maximum hour flow for the year in MGD
Mil gal -- million gallons
MGD -- million gallons per day
Price -- amount charged user
Retail service area -- area in which water is retailed by the utility
Revenue-producing water (RPW) -- the water measured as metered consumption and paid for by wholesale and retail customers within the service area
Treated water -- the amount of water treated through the water department's treatment plant
SMSA -- standard metropolitan statistical area
Source water -- raw water from ground or surface supply

METRIC CONVERSION TABLE

English Units	Metric Equivalents
1 foot	0.305 meters
1 mile	1.61 kilometers
1 sq mi	2.59 sq kilometers
1 mil gal	3.79 thou cu meters
1 $/mil gal	0.26 $/thou cu meters

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SECTION I

EXECUTIVE SUMMARY

A two-year study of 12 selected water utilities was undertaken to determine the economics of water delivery. Data were collected from at least one class A water utility (revenues greater than $500,000/year) in each of U. S. Environmental Protection Agency's (EPA) 10 regions. The finished water from all utilities selected meets the 1962 Public Health Service Drinking Water Standards. Volume I of this report provides in-depth analyses for five of the 12 utilities studied: Cincinnati, Ohio; Kansas City, Missouri; Fairfax County Water Authority in Fairfax, Virginia; Dallas, Texas; and the Elizabethtown Water Company in Elizabeth, New Jersey. Aggregate analysis of data from all the utilities is also provided in Volume I, along with an evaluation of factors affecting the cost of water supply and a consideration of the impact of technologies that might be used to satisfy requirements of the Safe Drinking Water Act.

Volume II contains the basic data from each of the 12 utilities studied. They represent many institutional arrangements, physically different water supply systems, and different conditions faced by water utilities across the United States. For example, Cincinnati and Kansas City are single-source utilities distributing water to far-flung distribution areas. Others, such as the Dallas Water Utility and the Fairfax County Water Authority, are in rapidly growing areas with capital costs distributed over a fast growing, revenue-producing base that keeps water costs low. Two investor-owned utilities, Elizabethtown Water Company and New Haven Water Company, were included in the sample to demonstrate problems associated with investor-owned utilities. The San Diego and Phoenix utilities operate in water-short areas. Pueblo and Kenton County were the smallest utilities studied. Seattle has made extensive investments in controlled source protection, and Orlando uses groundwater from a deep aquifer.

Data were collected for 10 years in five operating cost categories and two capital cost categories. The operating cost categories are support services, acquisition, treatment, power and pumping, and transmission and distribution. Capital costs were dived into interest and depreciation. Each operating cost category was examined as to total expenditures, unit costs, and percent of total cost. Revenue-producing water was used for all unit cost calculations because it represents the basis on which utilities obtain their operating revenues. The impact of operating expenditures, increasing labor costs, and increasing labor productivity on total water production costs were examined.

A systems evaluation was made for each utility in which the service area was divided into its components. Schematic diagrams of the system components have been developed for each of the utilities studied. For some utilities, these diagrams are very detailed, and for others, because of the complexity of the system, the diagram is somewhat superficial. By using the systems diagram and the previous cost categorizations, it was possible to evaluate the costs associated with delivering water to various subsections of the distribution system and to make some estimates as to how the costs of water vary throughout the distribution area.

Individual and comparative analyses reveal certain trends. Labor cost is a significant part of the annual operating costs for all utilities and has nearly doubled in some cases over the period of analysis. More and more dollars are being shifted into support service activities. Examination of water delivery costs shows that they increase with the distance from the treatment plant; thus there are definite limits to the efficient size of water utility service areas.

Mathematical models have been developed that relate labor cost ($/man-hour), productivity (man-hours/million gallons (mil gal)), and production (revenue-producing water) to annual operating costs. Another model has been developed for annual capital costs incorporating revenue-producing water and depreciation.

Extrapolations have been made with historical data for future water costs. Estimates for meeting the Safe Drinking Water Act's organic standards have been superimposed on these costs. Between 1974 and 1980, it is estimated that the price of water will have increased by 36% as a result of normal inflation and increased demands. For those few utilities required, under the Safe Drinking Water Act, to install the most expensive control technology (granular activated carbon), costs will increase an additional 24% above the expected 1980 level.

Total costs for each of the 12 utilities during the latest year of data collection are shown in Table 1. Taxes for the investor-owned utilities are reported separately. This analysis provides a mechanism for comparing utilities.

We hope these data will provide useful information on water supply costs from various utility systems and an example of the means by which data can be collected from water supplies to provide comparative information. With the advent of the Safe Drinking Water Act, regulatory agencies, utility managers, and the public should be able to isolate and understand various cost impacts on utilities of inflation and expansion demand versus regulatory impacts. The approach suggested here will allow the utility manager to pinpoint areas where costs are spiraling out of control and allow him to take corrective action. Table 2 summarizes some of the expected cost increases resulting from inflation and demand, as well as the effects of add-on technologies.

TABLE 1. COST ANALYSIS SUMMARY FOR LATEST YEAR OF RECORD (1974)

Utility	Revenue-producing water (mil gal)	Cost categories ($/mil gal)					
		Support services	Acquisition	Treatment	Distribution	Interest	Total
Kansas City	26,855	$ 145	$ 15	$ 82	$ 138	$ 50	$ 430
Dallas	63,030	83	25	52	120	58	338
San Diego	47,192	96	277	28	106	7	514
New Haven	17,714	113	29	15	106	117	560*
Fairfax Co.	19,232	88	35	56	134	209	522
Phoenix	63,661	91	17	47	112	53	320
Kenton Co.	2,259	82	12	103	124	73	394
Orlando	12,522	110	42	22	135	85	394
Elizabeth	38,256	89	67	33	144	113	492+
Pueblo	6,793	99	38	84	232	164	617
Seattle	45,967	109	37	13	77	27	263
Cincinnati	38,104	85	17	36	139	18	295

* Includes $179 taxes.

+ Includes $76 taxes.

TABLE 2. EXPECTED INCREASE IN COSTS FOR 1980

Item	Cost in 1975	Expected cost in 1980	1980 costs with add-on technologies		
			GAC - contractors	GAC - media replacement	Chlorine dioxide
Treatment operating cost ($/yr in millions)	1.10	1.50	2.97	4.17	2.17
Treatment capital cost ($/yr in millions)	0.48	0.60	3.34	1.33	0.73
Total operating cost ($/yr in millions)	8.85	12.40	13.87	15.07	13.07
Total capital cost ($/yr in millions)	3.80	4.95	7.69	5.68	5.08
Total production cost ($/yr in millions	12.75	17.35	21.56	20.75	18.25
Total unit cost ($/mil gal)	412.00	480.00	596.47	574.06	504.90

SECTION 2

INTRODUCTION

The Safe Drinking Water Act of 1974 will bring about fundamental changes in the way drinking water is handled before it is delivered to consumers. The Act establishes primary health-related standards and secondary or aesthetic-related but nonenforceable guidelines for drinking water supplies. Throughout the Act, emphasis is placed on the need to consider the economics of water delivery.

In response to this need, a 2-year study of selected water utilities was undertaken in which data were collected from at least one Class A water utility (revenues greater than $500,000/year) in each of the U. S. Environmental Protection Agency's 10 regions. Figure 1 shows the location of the utilities studied. Twelve utilities were selected for investigation--one in regions I, II, III, V, VI, VII, VIII, and X and two in regions IV and IX. The study, which ran from 1974 through 1976, was conducted in two phases with a special study in Cincinnati, Ohio. Data were collected so that costs could be easily compared among utilities.

Each utility's services were divided into the functional areas of acquisition, treatment or purification, and distribution. These functional areas or subsystems are common to all water supply delivery systems and can therefore provide a common basis for data collection. Another category common to all water utilities is the management or administrative function which completes the framework of the institution for insuring an adequate supply of safe drinking water. This institution is most commonly called a water supply utility.

Costs were categorized as either operating or capital expenditures. Operating costs have been assigned to the following functional areas: acquisition, treatment, power and pumping, transmission and distribution (including storage), and support services. The first four functional areas are related to the physical delivery of water, and the fifth, support services, is related to the overall integrative responsibility of utility management. Operating costs include operating labor, maintenance, and materials. For example, if the utility has a treatment division, laboratory personnel costs are included in the treatment cost category, but management costs for the division are included in the support services category. Support services include, therefore, all of the administrative and customer services that are required to manage the water utility and collect revenues but that are not directly related to the physical process of delivering water.

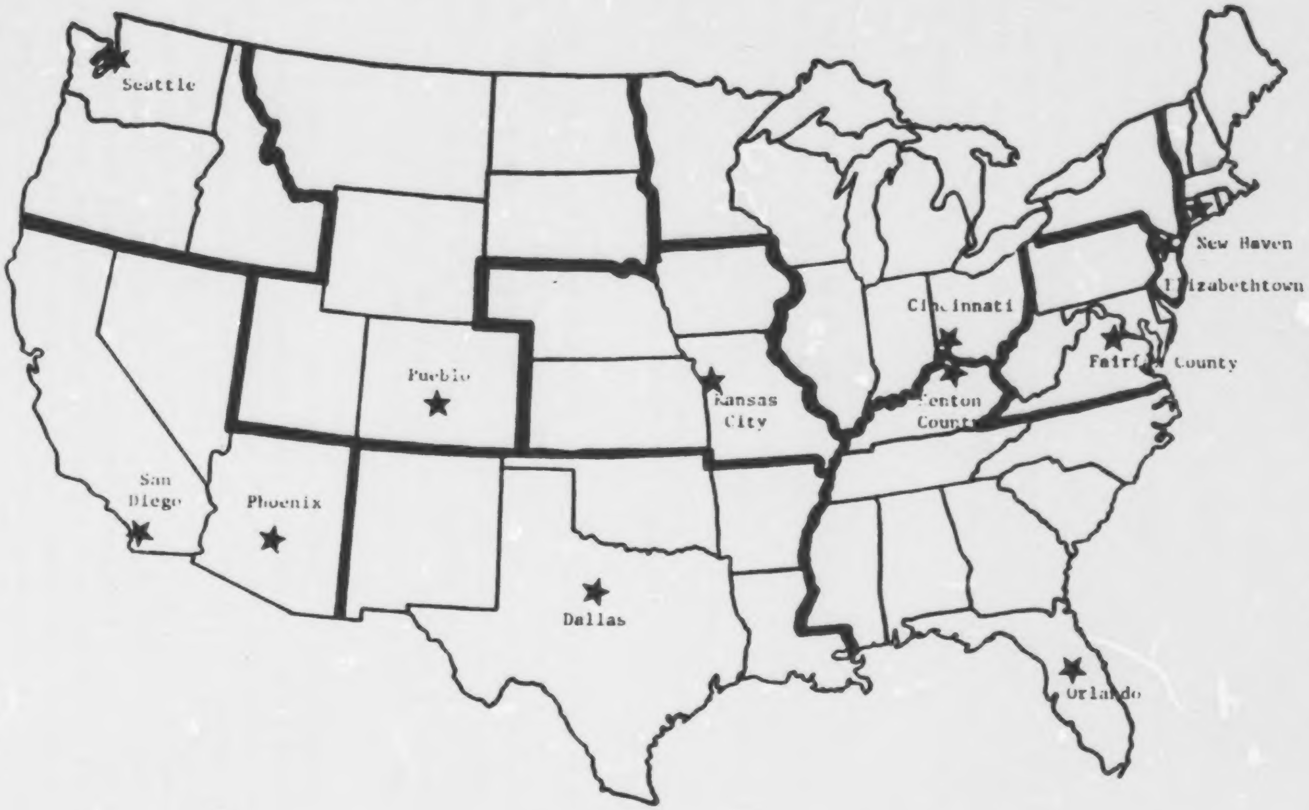

Seattle
San Diego
Phoenix
Pueblo
Dallas
Kansas City
Cincinnati
Kenton County
Fairfax County
New Haven
Elizabethtown
Orlando

Figure 1. Location of water utilities studied.

Capital costs are assumed as depreciation and interest for the plant-in-service. Depreciation is based on the historic cost of the facility divided by its useful life, and not on the costs required to reproduce the facility. Lower costs will therefore be associated with older utilities. Most of the utilities analyzed constructed the major portion of their facilities in the 1930's and 40's. Interest costs are the dollars the utilities must pay for their bonds or other money raising mechanisms.

Revenues were not considered in this report. All of the data reported are strictly related to the cost of water supply and do not include some of the broader aspects of elasticity of demand and optimal pricing policies of water supply. All costs reported are based on revenue-producing water (RPW) pumped by the utilities for a 10-year period from 1965 through 1974.

The report has been prepared in two volumes. Volume I contains summary information and an analysis of the factors that affect the cost of water supply, and Volume II contains the basic data from each of the selected utilities.

SECTION 3

CONCLUSIONS

Data from the 12 utilities studied here are representative of many utilities in the United States. Distributed across the country, the 12 utilities studied reflect differences in wage rates and costs for various items throughout the United States. The cost of water supply has been continually increasing as a result of increased capital and labor costs, labor wage rates, costs of chemicals and other supplies, and increased demand for water. However, a decrease in the number of man-hours required to supply 1 million gallons (mil gal) of water has moderated these cost increases. In many cases, when the unit cost of water is modified by the Consumer Price Index (CPI), costs have actually decreased with time.

Equations developed in Volume 1 show that when water conservation measures are adopted, increasing wage rates and other inflationary effects will increase the cost of water in accordance with other cost increases in the economy. Such increases are inevitable and should be anticipated.

The methodology used for collecting these data can be applied to water utilities not included in this study. Such an application would provide for a comparative and standardized analysis of water supply costs for all utilities. This effort is intended as a model for other related data collection efforts.

SECTION 4

OVERVIEW AND AGGREGATE DATA ANALYSIS

Revenue-producing water from all 12 utilities increased by approximately 50% over the 10-year period studied (1965-74) (Figure 2).

Average costs for the five major operating cost categories all showed substantial increases over time (Table 3). Support services increased from an average of slightly over $1 million/year to more than $3 million/year, or by nearly 200%. The other categories increased by slightly more than 100%, with the exception of transmission and distribution, which increased by approximately 73%.

Unit costs had considerably smaller increases or remained stable during the 10-year period (Table 4). Support services unit cost increased nearly 63%, transmission and distribution stayed nearly the same, and total expendutires increased by less than 50%.

The five operating cost categories varied as a percent of total operating cost (Table 5). Support services increased from 26% to slightly over 31%, and treatment, power and pumping, and transmission and distribution decreased as percents of total operating cost.

Average operating and capital costs for all 12 utilities more than doubled during the 10-year period (Table 6). Operating expenditures increased by 127%, and capital expenditures increased by 78%. Unit costs increased by only 25%.

Average operating and capital expenditures ratios for the 12 utilities studied are shown in Table 7. Operating expenses increased as a percent of total cost from 64.5% in the first year of analysis to nearly 70% by the last year, whereas capital cost dropped from 35.5% in the first year of analysis to just over 30% in the last year.

The impact of labor and operating costs for water supply are shown in Table 8. Labor costs accounted for 42% of the utilities' operating costs in the first year of analysis and 42% in the last year. The average cost/man-hour increased 82%, but the ratio of man-hours/mil gal of RPW decreased by 16%. Table 8 shows a steady decrease in capital/labor cost ratio. Although economies of scale were in effect with respect to the number of man-hours used to produce water, this cost reduction was nullified by wage increases. Labor is therefore a very important factor in what is typically presumed to be a capital intensive industry.

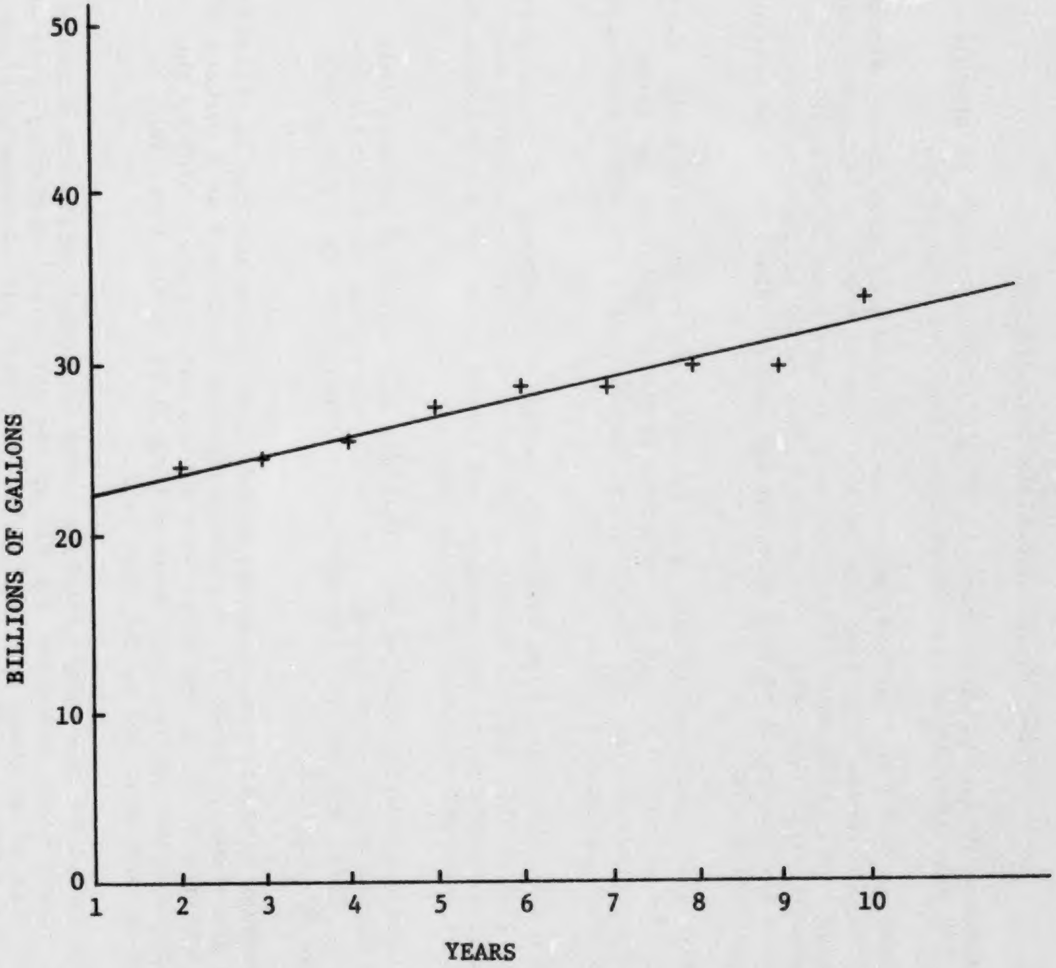


Figure 2. Average annual revenue-producing water for all 12 utilities.

TABLE 3. AVERAGE OPERATING COSTS FOR MAJOR OPERATING COST CATEGORIES

Operating cost category	Year									
	1	2	3	4	5	6	7	8	9	10
Support services	$1,126,622	$1,198,861	$1,474,482	$1,560,884	$1,837,836	$2,031,880	$2,268,728	$2,437,329	$2,705,626	$3,127,558
Acquisition	981,998	1,007,698	978,196	1,062,491	1,231,310	1,289,012	1,537,034	1,770,871	1,990,661	2,356,385
Treatment	539,946	577,796	617,713	630,019	701,651	783,581	1,013,585	913,933	998,003	1,212,659
Power and pumping	789,402	830,034	922,020	870,937	933,141	955,478	1,042,051	1,172,427	1,294,861	1,805,530
Transmission and distribution	890,750	927,939	978,982	1,044,549	1,108,421	1,213,655	1,320,415	1,439,312	1,548,570	1,541,550

TABLE 4. AVERAGE UNIT COSTS FOR MAJOR OPERATING COST CATEGORIES
($/mil gal metered consumption

Operating cost category	Year									
	1	2	3	4	5	6	7	8	9	10
Support services	$55.29	$54.6	$62.51	$61.89	$71.66	$76.19	$79.35	$83.49	$91.72	$89.98
Acquisition	48.27	45.91	41.46	42.22	48.08	48.20	53.75	60.69	67.42	67.43
Treatment	26.58	26.27	26.10	25.0	27.44	29.39	35.41	29.63	33.85	35.01
Power and pumping	38.70	37.85	38.94	34.43	36.51	35.74	36.42	40.29	43.98	52.08
Transmission and distribution	43.81	42.19	41.46	41.40	43.32	45.38	46.21	49.30	52.37	44.27

TABLE 5. AVERAGE OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Operating cost category	Year									
	1	2	3	4	5	6	7	8	9	10
Support services	26.0	26.4	29.7	30.2	31.6	32.4	31.6	31.5	31.7	31.1
Acquisition	22.7	22.2	19.7	20.6	21.2	20.5	21.4	22.9	23.3	23.5
Treatment	12.5	12.7	12.4	12.2	12.1	12.5	14.1	11.8	11.7	12.1
Power and pumping	18.2	18.3	18.5	16.8	16.1	15.2	14.5	15.2	15.2	18.0
Transmission and distribution	20.6	20.4	19.7	20.2	19.1	19.3	18.4	18.6	18.1	15.3

TABLE 6. AVERAGE OPERATING AND CAPITAL COSTS

Item	Year									
	1	2	3	4	5	6	7	8	9	10
Operating cost ($)	4,074,911	4,272,278	4,579,474	5,030,824	5,830,681	6,285,280	6,934,452	7,598,149	8,431,726	9,262,730
Depreciation ($)	1,241,563	1,296,702	1,430,217	1,547,238	1,604,659	1,661,276	1,693,273	1,828,003	1.904,825	2,145,428
Interest ($)	996,955	920,622	948,614	1,286,566	1,267,062	1,428,970	1,411,346	1,488,971	1,707,623	1,848,256
Total cost ($)	6,313,429	6,490,102	6,958,305	7,864,628	8,702,402	9,375,526	10,039,071	10,915,123	12,044,174	13,256,414
Unit cost ($/mil gal)	332.88	322.45	328.39	327.39	340.26	354.23	370.57	387.88	425.93	416.74

TABLE 7. OPERATING AND CAPITAL EXPENSE RATIOS

Item	Year									
	1	2	3	4	5	6	7	8	9	10
Operating cost ($)	4,074,911	4,272,278	4,579,474	5,030,824	5,830,681	6,285,280	6,934,452	7,593,149	8,431,726	9,262,730
Capital cost ($)	2,238,518	2,217,324	2,378,831	2,833,804	2,871,721	3,090,246	3,104,619	3,316,924	3,612,448	3,993,684
Interest ($)	996,955	920,622	948,614	1,286,566	1,267,062	1,428,970	1,411,346	1,488,971	1,707,623	1,848,256
Total cost ($)	6,313,429	6,490,102	6,958,305	7,864,628	8,702,402	9,375,526	10,039,071	10,915,123	12,044,174	13,256,414
Operating cost as % of total	64.5	65.8	69.4	64.0	67.0	67.0	69.1	69.6	70.0	69.9
Capital cost as % of total	35.5	34.2	30.6	36.0	33.0	33.0	30.9	30.4	30.0	30.1

TABLE 8. MANPOWER COSTS

Item	Years									
	1	2	3	4	5	6	7	8	9	10
Total payroll ($)	1,713,806	1,825,217	2,006,525	2,237,453	2,525,527	2,724,751	3,040,661	3,392,529	3,665,588	3,857,361
Total hours for O&M Payroll	659,156	683,602	716,616	743,340	756,145	754,778	787,736	794,503	816,389	813,789
Metered consumption (mil gal)	22,193	23,930	24,619	25,864	27,456	28,736	28,904	30,159	29,857	34,169
Total payroll/metered consumption ($/mil gal)	77.22	76.27	81.50	86.51	91.98	94.82	105.28	112.49	122.77	112.89
Total hours/metered consumption (hr/mil gal)	33.75	32.50	30.42	29.85	31.17	29.70	30.32	29.83	30.50	28.32
Average cost/man-hour ($)	2.60	2.67	2.80	3.01	3.34	3.61	3.86	4.27	4.49	4.74
Capital/labor cost ratio	1.31	1.21	1.18	1.27	1.14	1.13	1.02	0.98	0.99	1.04

SECTION 5

CINCINNATI WATER WORKS

The City of Cincinnati is located in Hamilton County in southwestern Ohio. Based on the 1970 census, the city has a population of 452,524, and the county, 924,018. During the past few years, both the city and the county have been declining in population. Some system facts are shown in Table 9.

WATER SUPPLY SERVICE AREA

The Cincinnati Water Works, owned and operated by the City of Cincinnati, is a self-sustaining public utility. It is metropolitan both in nature and scope since water is served to areas outside the city limits.

In 1955, the City of Cincinnati and Hamilton County joined in a contract that stipulated that the Cincinnati Water Works would serve approximately 80% of Hamilton County for a period of 30 years (Figure 3). In 1961, the Water Works contracted to serve a portion of Butler County, and in 1967 a portion of Warren County was added. A number of communities maintain their own systems but are surrounded by the Cincinnati Water Works service area. Emergency service is provided to most of them, but as long as their source of supply can be maintained, most of the communities will not change their present status. The distribution area and the facilities used are shown in Figure 4. One city has its own distribution system, but it is served by the Cincinnati Water Works.

The Cincinnati Water Works currently serves over 186,000 accounts through more than 3,785 miles of water mains. It has been expanding at the rate of 3,000 accounts and 35 miles of mains each year. In 1974, the Water Works supplied approximately 840,000 people at a daily rate of 132.9 mil gal (almost 158 gallons/capita/day). The amount of water supplied might be greater except for the large amount of well water available in the area to consumers who wish to develop their own supplies. One private water purveyor supplies approximately 17 MGD for industrial use.

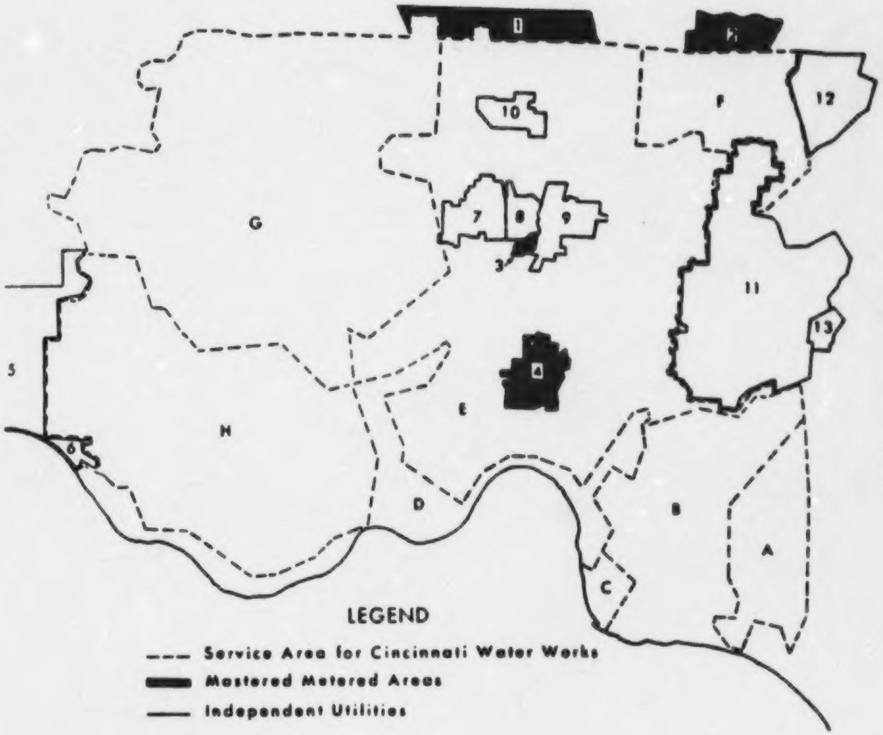
ORGANIZATION

The Cincinnati Water Works serves only as a water utility, but it does collect revenue for the Metropolitan Sewer District. The structure of the organization depicted in Figure 5 is composed of administration, supply, distribution, and commercial divisions.

TABLE 9. CINCINNATI WATER WORKS, BASIC FACTS*

Item	Amount
Population:	
City	452,524
County	924,018
Retail service area	840,000
Area of retail service area (sq miles)	312.73
Number of metered customers	186,000+
Percent metered	100
Source water	100% Surface (river)
Pipe in system (miles)	3,785
Elevation of treatment plant (ft above mean sea level)	532
Elevation of service area (min - max)	500 - 1001
Revenue-producing water (mil gal)	38,104
Treated water (mil gal)	48,627
Maximum day/maximum hour (MGD)	237/231

* 1973 data.


1
2
12
10
F
G
7
8
9
3
11
13
5
4
E
H
6
D
B
A
C
LEGEND
Service Area for Cincinnati Water Works
Mastered Metered Areas
Independent Utilities

CINCINNATI SERVICE AREAS

A. Cherry Grove
B. Mt. Washington
C. California
D. Central
E. Eastern Hills
F. Brecon
G. Western Hills North
H. Western Hills South

MASTER METERED AREAS

1. Butler County
2. Warren County
3. Arlington Heights
4. Norwood

INDEPENDENT UTILITIES

5. Cleves
6. Addison
7. Wyoming
8. Lockland
9. Reading
10. Glendale
11. Indian Hill
12. Loveland
13. Milford

Figure 3. Cincinnati Water Works service area.

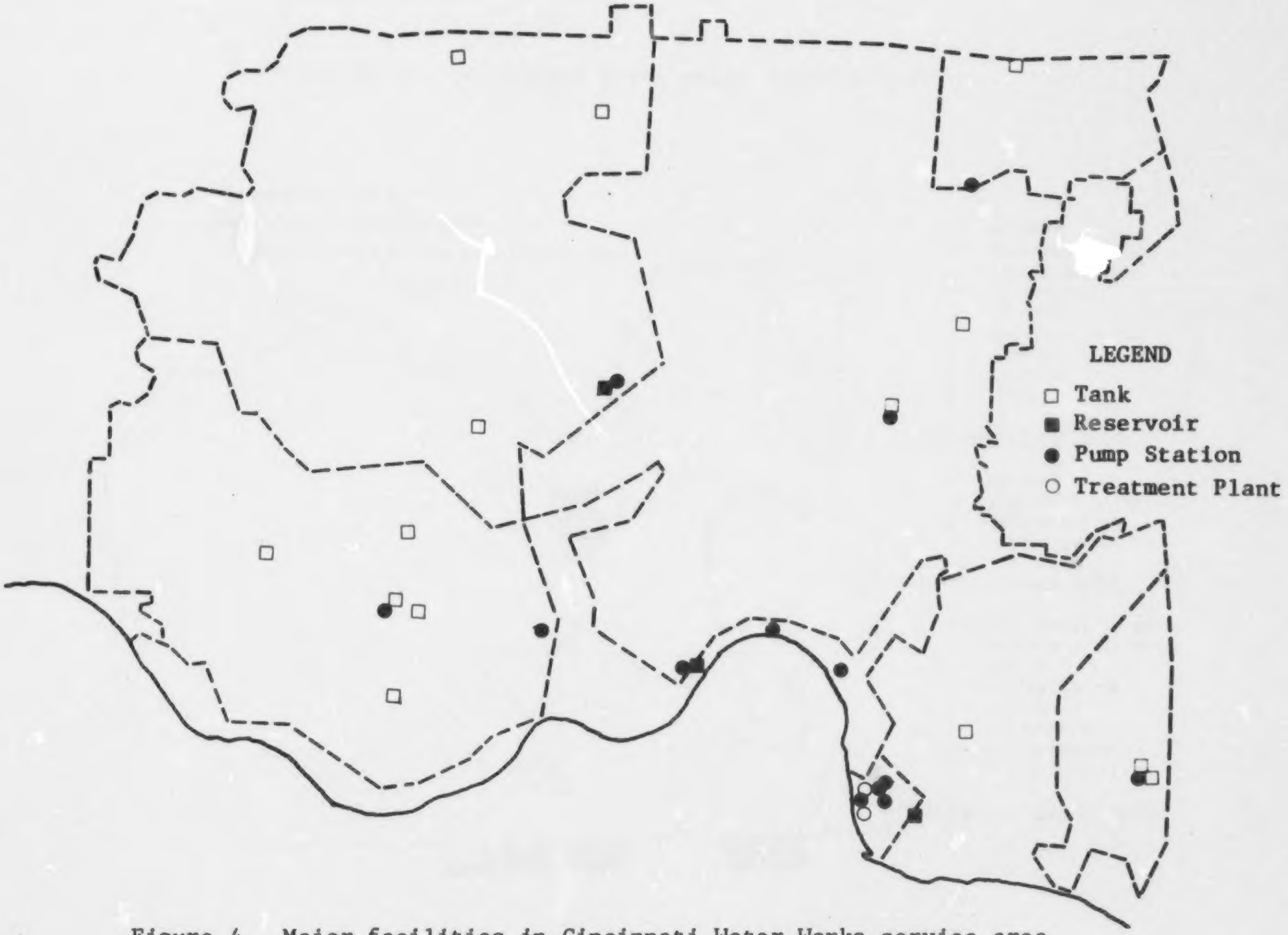

LEGEND
□ Tank
■ Reservoir
● Pump Station
○ Treatment Plant

Figure 4. Major facilities in Cincinnati Water Works service area.

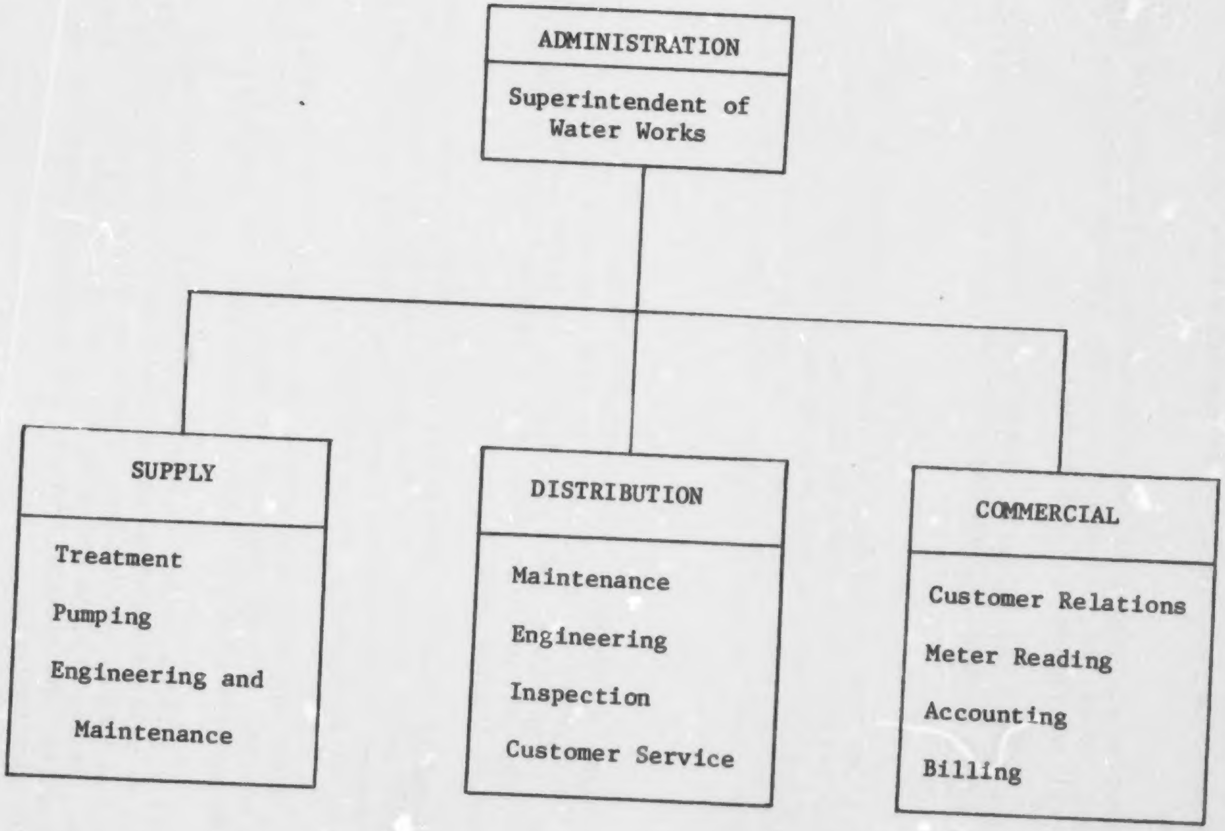

ADMINISTRATION
Superintendent of Water Works
SUPPLY
Treatment
Pumping
Engineering and Maintenance
DISTRIBUTION
Maintenance
Engineering
Inspection
Customer Service
COMMERCIAL
Customer Relations
Meter Reading
Accounting
Billing

Figure 5. Cincinnati Water Works organizational chart.

The administrative division plans all system improvements, analyzes the adequacy of the system, develops the rate structure, and coordinates long-range plan development.

The supply division handles treatment, pumping operation, and some engineering and maintenance, especially in connection with new facilities or replacements.

The distribution division involves engineering, inspection, and maintenance of tanks, reservoirs, and equipment. The customer service section maintains and replaces meters for each account.

Finally, the commercial division controls the accounts receivable, which includes meter reading, accounting, billing, and customer relations.

ACQUISITION

Raw water comes from an intake pier located in Kentucky on the south side of the Ohio River. Water obtained through this pier is pumped to two nearby settling basins having a combined capacity of 372 mil gal. As water flows to the settling basins, chlorine, alum, and activated carbon may be added as needed. From the settling basins, water flows by gravity to the treatment plant.

TREATMENT

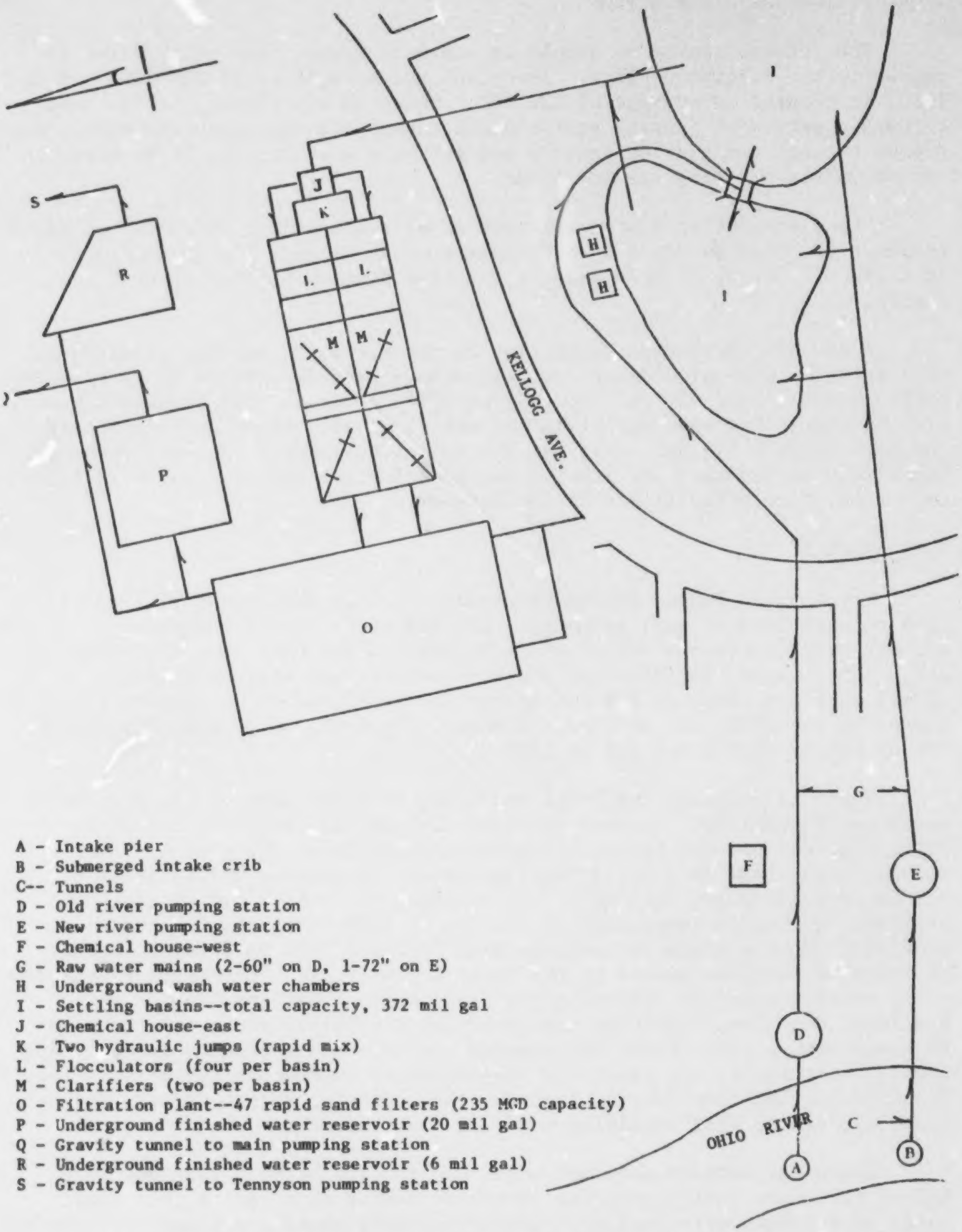
All raw water is treated at the complex in California, Ohio, just east of Cincinnati. The treatment plant, built in 1936, contains facilities for chemical treatment, coagulation, and flocculation; 47 filter beds, each with a capacity of 5 MGD; and two clear wells with a combined capacity of 28.3 mil gal for storage of treated water.

In the chemical treatment processes, six chemicals are fed in proportion to the amount of water treated, but the quality of the raw water determines the specific amount of each chemical used. The chemicals used, their purpose, and their order of application are as follows:

1. Chlorine, alum, and activated carbon may be added before pumping to the settling basins. The purpose here is basically taste and odor control as well as control of algae. Alum is also used for coagulation.

2. Lime, ferric sulfate, soda ash (sodium carbonate), and activated carbon are added as water flows from the settling basins through the chemical house to the coagulating basins. Provision exists for necessary chlorine addition. Ferric sulfate and alum are used for coagulation. Lime and soda ash affect the mineral content, and activated carbon is used for taste and odor control.

3. Once the water leaves the filter house, it is collected in the clear wells. At this point, chlorine and soda ash can again be added as needed. Figure 6 shows the plan of the Cincinnati treatment plant.



A - Intake pier
B - Submerged intake crib
C-- Tunnels
D - Old river pumping station
E - New river pumping station
F - Chemical house-west
G - Raw water mains (2-60" on D, 1-72" on E)
H - Underground wash water chambers
I - Settling basins--total capacity, 372 mil gal
J - Chemical house-east
K - Two hydraulic jumps (rapid mix)
L - Flocculators (four per basin)
M - Clarifiers (two per basin)
O - Filtration plant--47 rapid sand filters (235 MGD capacity)
P - Underground finished water reservoir (20 mil gal)
Q - Gravity tunnel to main pumping station
R - Underground finished water reservoir (6 mil gal)
S - Gravity tunnel to Tennyson pumping station

Figure 6. Cincinnati Water Works supply division.

TRANSMISSION AND DISTRIBUTION

The current source of supply is the Ohio River, from which water is pumped to the treatment plant. The plant has a capacity of 235 MGD, and in 1973, it treated an average of 136 MGD. Water is distributed to the east through a series of pumping stations and tanks. To the north and west, water passes through two gravity tunnels and two pump stations and it is then repumped into outlying service areas.

The distribution system consists of approximately 3,785 miles of mains composed of 3- to 60-in. pipe. The two gravity tunnels are 84 and 96 in. in diameter. Figure 7 provides a simplified diagram of the transmission system.

There are 17 storage facilities in the system to provide pressure as well as 152.7 mil gal storage for peak demand periods. There is an elevation difference of about 500 ft between the hilly zones and the treatment plant. Five of the 17 storage facilities are not elevated. They have a combined capacity of 96.6 mil gal. All but the Sutton Road Reservoir have pumping capability to increase pressure in the distribution system. Table 10 lists the water storage facilities in the network.

COST ANALYSIS

Total water pumped by the Cincinnati utility during calendar years 1964 through 1973 as well as metered RPW and water that was accounted for but did not produce revenue are shown in Figure 8. All cost data are based on RPW; for example, purification costs in dollars per million gallons ($/mil gal) are based on RPW and not on the total number of gallons of water pumped by the utility. As Figure 8 shows, the total water pumped exceeded RPW by nearly 13,000 mil gal in 1973.

Table 11 contains the total operating cost for each of the previously mentioned categories. Support services includes all of those operating costs that support but are not directly chargeable to the production of water. Such items as general administration, accounting and collection, and meter reading are included. The subcategory "Other", which includes pensions, workman's compensation, charges by other city departments, and security, shows a sharp increase between 1968 and 1969 as a result of the addition of fulltime guards to the Water Works staff. Purification includes those costs related to operating the laboratory, labor involved in the treatment function, chemicals for purifying the water, and maintenance of the treatment plant. Power and pumping includes costs related to operating labor, maintenance, and power for pumping water throughout the service area. Transmission and distribution includes the operating labor and maintenance costs associated with supplying water to the consumer.

Costs for support services more than doubled between 1964 and 1973. All of the other cost categories increased during this period, but their rates of increase were smaller. Total operating costs increased by about 65%.

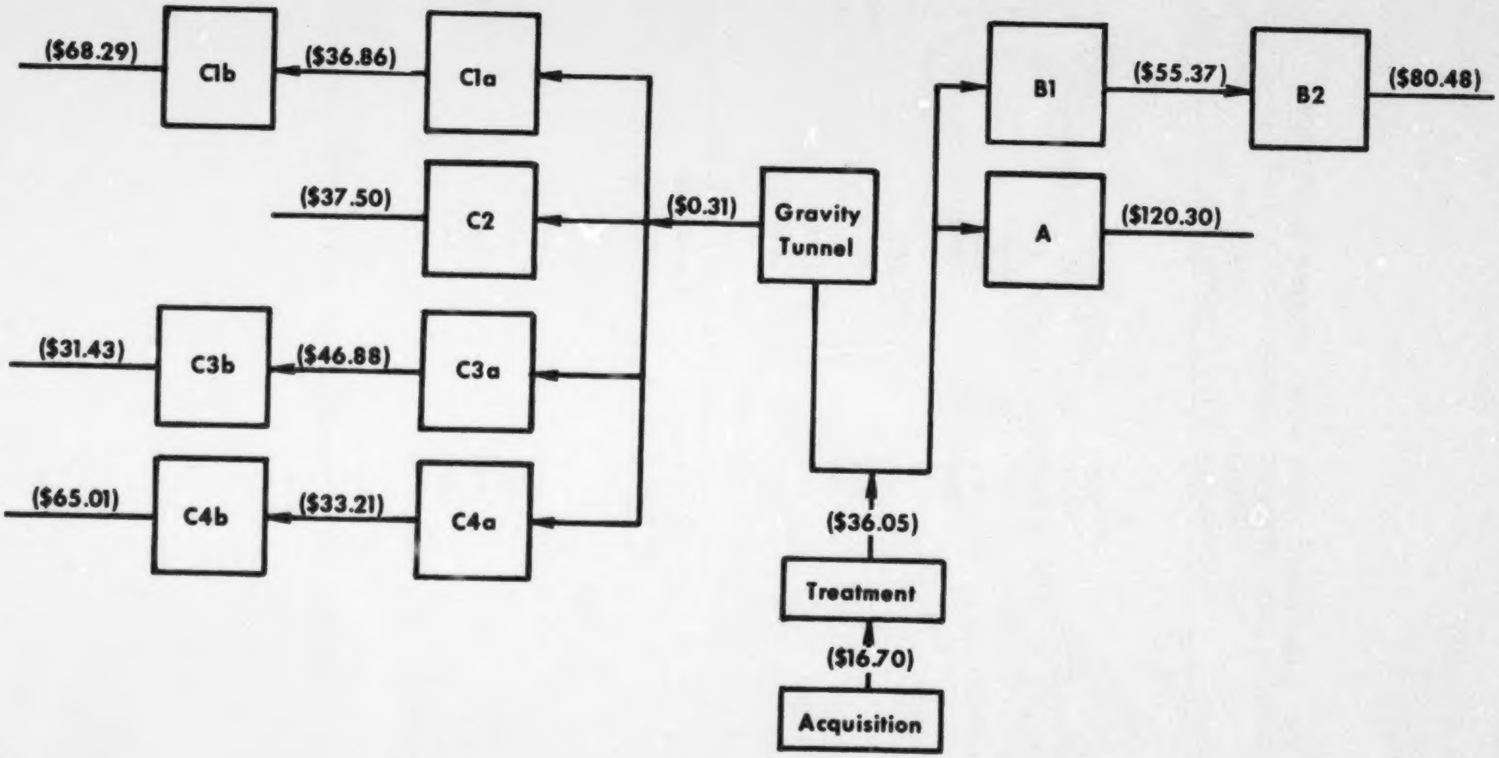

($68.29)
C1b
($36.86)
C1a
($37.50)
C2
($31.43)
C3b
($46.88)
C3a
($65.01)
C4b
($33.21)
C4a
($0.31)
Gravity Tunnel
B1
($55.37)
B2
($80.48)
A
($120.30)
($36.05)
Treatment
($16.70)
Acquisition

Figure 7. Schematic diagram of treatment plant costs ($/mil gal) in the Cincinnati Water Works system. A, B1, B2, etc. denote service areas. (See Figure 9 for geographic locations.)

TABLE 10. CINCINNATI WATER WORKS STORAGE FACILITIES

Type of storage	Ground elevation (ft)	Overflow elevation (ft)	Capacity (mil gal)
Tank storage:			
Brecon elevated	955	990	1
Cherry Grove elevated	1001	1030	1
Cherry Grove tank	887	950	2
Delhi Hills tank	995	1030	2
Ferguson Road tanks	966	1028	1.4
Greenhills tank	898	950	1.5
Kugler Mill elevated	930	960	1
Mack tank	995	1030	2
Mt. Airy tanks	966	1028	8.5
Mt. Washington tank	808	950	1.2
Pleasant Run elevated	995	1030	2
Wardall elevated	995	1030	2.5
	Elevation bottom (ft)	Elevation top (ft)	Capacity (mil gal)
Ground storage:			
Eden Park Reservoir	643	682	80
Kennedy underground	829	845	6
Summit underground	868	882	4.9
Sutton Road Reservoir	660	683	1.1
Winton Road Reservoir	920	950	34.6
Total capacity	---	---	152.7

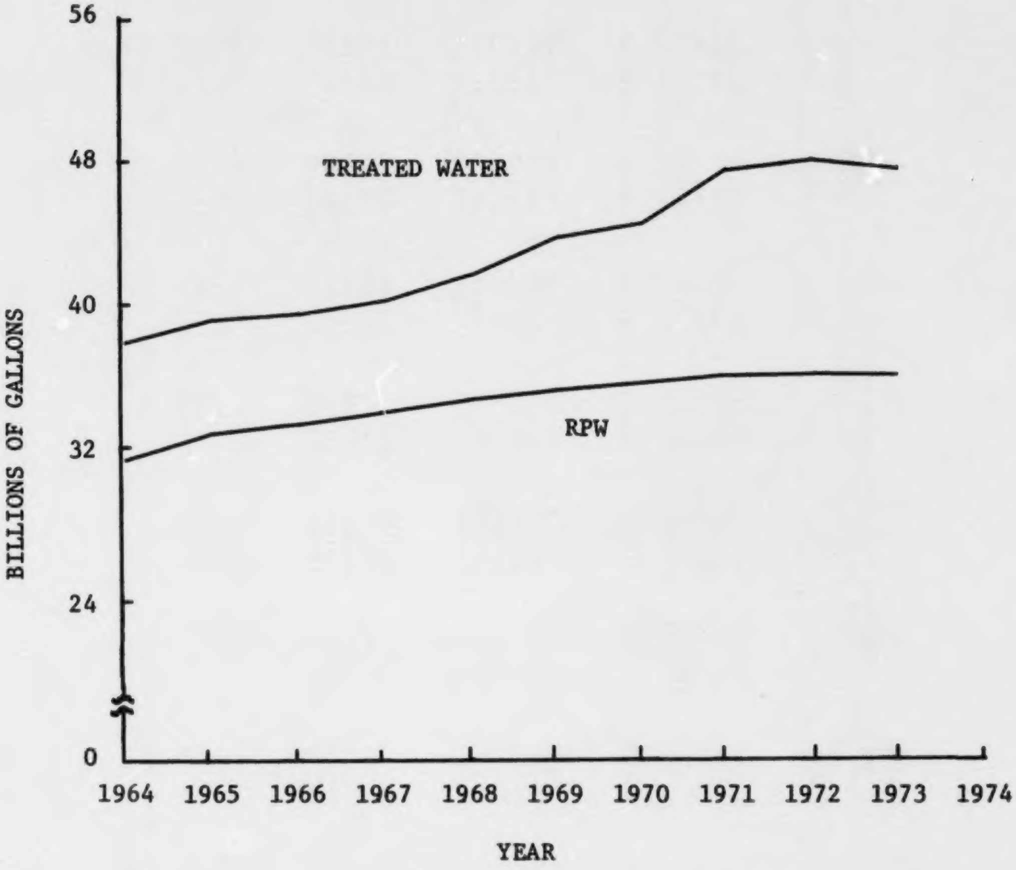


Figure 8. Cincinnati Water Works water flow, 1964 to 1973: treated water versus RPW.

TABLE 11. CINCINNATI WATER WORKS ANNUAL OPERATING COSTS

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	$235,834	$243,870	$250,774	$295,445	$306,583	$336,236	$359,307	$384,356	$465,136	$451,404
Acctg and collection	282,963	278,983	292,656	324,660	395,372	410,427	422,221	480,680	533,285	585,288
Service	225,768	233,539	245,552	249,206	256,748	302,611	300,214	351,596	370,723	407,787
Other	615,177	574,111	624,059	629,284	647,647	1,059,359	999,165	1,155,109	1,264,105	1,321,758
Total support services	1,359,742	1,330,503	1,413,041	1,498,595	1,616,350	2,108,633	2,080,907	2,371,741	2,633,249	2,766,237
Acquisition	394,844	368,762	374,229	372,385	379,928	405,149	426,743	496,344	480,020	485,102
Treatment:										
Laboratory	31,434	38,493	42,706	41,219	32,315	37,934	39,801	38,381	42,154	46,940
Operating labor	149,426	144,277	152,633	164,778	169,750	180,574	188,150	143,383	167,608	172,754
Chemicals	409,463	367,234	375,132	410,700	411,143	410,172	426,248	423,667	424,586	384,698
Maintenance	170,180	196,119	187,569	216,698	216,442	246,220	223,697	315,748	323,127	334,765
Other	152,710	160,352	175,827	171,299	182,267	166,132	187,145	243,424	282,744	270,910
Total treatment	913,213	906,475	933,867	1,004,694	1,011,917	1,041,032	1,065,041	1,164,603	1,240,219	1,210,067
Power and pumping:										
Operating labor	199,620	202,322	223,715	232,845	228,061	255,809	272,235	239,756	232,280	238,806
Maintenance	182,915	182,814	216,483	226,307	238,245	304,739	252,469	346,596	320,396	309,375
Power	581,588	606,176	613,971	645,362	629,906	696,544	694,359	870,796	902,790	903,397
Other	122,039	124,036	128,545	151,493	150,925	154,805	163,001	181,262	179,479	215,554
Total power and pumping	1,086,162	1,115,348	1,182,714	1,256,007	1,247,137	1,411,897	1,382,064	1,638,410	1,634,945	1,667,132
Transmission and distribution:										
Operating labor	462,986	450,387	475,763	491,722	534,062	570,439	595,005	611,769	607,511	652,791
Maintenance	1,003,220	1,027,617	1,128,650	1,256,074	1,329,452	1,436,244	1,586,635	1,794,415	1,846,084	1,868,514
Other	91,989	75,792	106,959	137,468	64,201	77,331	141,096	80,963	152,840	132,579
Total trans. and distr.	1,558,195	1,553,796	1,711,372	1,885,264	1,927,715	2,084,014	2,322,736	2,487,147	2,606,435	2,653,884
Total operating cost	5,312,156	5,274,884	5,615,223	6,016,945	6,183,047	7,050,725	7,277,491	8,158,245	8,594,868	8,782,422

Table 12 contains the average unit operating costs for each major category based on the number of revenue-producing gallons pumped in a given year. All of the cost categories increased by a factor of less than two, and the total operating cost increased by about 40%.

Table 13 shows each cost category as a percent of total operating cost. Support services accounted for a significant and increasing portion of the utility's budget -- from 25.6% in 1964 to 31.5% in 1973. The other cost categories either decreased or remained constant.

Cincinnati's operating and capital expenses, as defined earlier, are shown on Table 14. Depreciation and interest are defined as the capital expenses for the waterworks system. They remained essentially constant, but operating expenses increased by approximately 65%. The percentage of expenditures allocated to capital decreased from approximately 27% to 22% during the period (Table 15). Operating expenditures are always reported in inflated or current dollars, and capital expenditures are depreciated in historical dollars over a long period of time. The problems related to the depreciation of capital will be discussed later. Since the support services category, which is labor intensive, played an increasingly important role in the cost of water supply, labor and manpower costs will be analyzed in the following section.

LABOR COST ANALYSIS

To evaluate the impact of labor costs on operating costs for water supply, it is necessary to examine the payroll of the water utility (Table 16). Labor costs accounted for 64% of the utility's operating costs in 1964 and for 62% in 1973. The average cost/man-hour increased 71%, and the number of man-hours/mil gal of metered consumption decreased by 23%. The bottom line in the table shows a decreasing capital/labor cost ratio. Although economies of scale were achieved with respect to the number of man-hours used to produce water, the effect on cost was nullified by wage increases. Table 16 therefore illustrates the importance of labor in what is typically presumed to be a capital intensive industry.

DEPRECIATION ANALYSIS

Capital expenditures make up a large portion of the cost of water supply. Depreciation reflects historical costs and not that of replacing a facility based on current costs. Historical costs refer to the original construction cost of a capital facility, and reproduction costs reflect the capital expenditures necessary to build an identical plant today. Historical cost is exact, but reproduction cost is based on the original investment modified by an appropriate index.

The reco[illegible] he Cincinnati Water Works show the historical value of the plant-in-se[illegible] to be $111.7 million. The value of pipelines, plant, or equipment previously replaced or fully depreciated is excluded.

TABLE 12. CINCINNATI WATER WORKS UNIT OPERATING COSTS ($/mil gal RPW)

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	$7.36	$7.38	$7.44	$8.65	$8.83	$9.29	$9.68	$10.08	$12.26	$11.84
Accounting and collection	8.82	8.44	8.68	9.50	11.39	11.34	11.38	12.61	14.06	15.37
Service	7.04	7.06	7.28	7.30	7.39	8.36	8.09	9.22	9.78	10.70
Other	19.19	17.36	18.50	18.42	18.94	29.26	26.91	30.29	33.33	34.69
Total support services	42.41	40.24	41.90	43.87	46.55	58.25	56.06	62.20	69.43	72.60
Acquisition	12.31	11.15	11.10	10.90	10.94	11.19	11.50	13.02	12.66	12.73
Treatment:										
Laboratory	.98	1.16	1.27	1.21	.93	1.05	1.07	1.01	1.11	1.23
Operating labor	4.66	4.37	4.53	4.82	4.89	4.99	5.07	3.76	4.42	4.53
Chemicals	12.77	11.11	11.12	12.02	11.84	11.33	11.48	11.11	11.19	10.10
Maintenance	5.31	5.93	5.56	6.34	6.23	6.80	6.03	8.28	8.52	8.78
Other	4.76	4.85	5.21	5.02	5.25	4.59	5.04	6.38	7.46	7.11
Total treatment	28.48	27.42	27.69	29.41	29.14	28.76	28.69	30.54	32.70	31.75
Power and pumping										
Operating labor	6.23	6.12	6.63	6.82	6.57	7.07	7.33	6.29	6.12	6.27
Maintenance	5.70	5.53	6.42	6.63	6.86	8.42	6.80	9.09	8.45	8.12
Power	18.14	18.34	18.21	18.89	18.14	19.24	18.71	22.84	23.80	23.71
Other	3.81	3.75	3.81	4.43	4.35	4.28	4.39	4.75	4.73	5.65
Total power and pumping	33.88	33.74	35.07	36.77	35.92	39.01	37.23	42.97	43.10	43.75
Transmission and distribution:										
Operating labor	14.44	13.63	14.11	14.40	15.38	15.76	16.03	16.04	16.02	17.13
Maintenance	31.29	31.08	33.46	36.77	38.29	39.68	42.75	47.07	48.67	49.04
Other	2.87	2.29	3.17	4.02	1.85	2.13	3.80	2.12	4.03	3.48
Total transmission and distribution	48.60	47.00	50.74	55.19	55.52	57.57	62.58	65.23	68.72	69.65
Total unit operating cost	165.68	159.55	166.50	176.14	178.07	194.78	196.06	213.96	226.61	230.48

TABLE 13. CINCINNATI WATER WORKS OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	4.4	4.6	4.5	4.9	4.9	4.8	5.0	4.7	5.4	5.1
Accounting and collection	5.3	5.3	5.2	5.4	6.4	5.8	5.8	5.9	6.2	6.7
Service	4.3	4.4	4.4	4.1	4.2	4.3	4.1	4.3	4.3	4.7
Other	11.6	10.9	11.1	10.5	10.6	15.0	13.7	14.2	14.7	15.0
Total support services	25.6	25.2	25.2	24.9	26.1	29.9	28.6	29.1	30.7	31.5
Acquisition	7.4	7.0	6.7	6.2	6.1	5.8	5.9	6.1	5.6	5.5
Treatment:										
Laboratory	.6	.7	.8	.7	.5	.5	.5	.5	.5	.5
Operating labor	2.8	2.7	2.7	2.7	2.8	2.6	2.6	1.7	1.9	2.0
Chemicals	7.7	7.0	6.7	6.8	6.7	5.8	5.8	5.2	4.9	4.4
Maintenance	3.2	3.7	3.3	3.6	3.5	3.5	3.1	3.9	3.8	3.8
Other	2.9	3.1	3.1	2.9	2.9	2.4	2.6	3.0	3.3	3.1
Total treatment	17.2	17.2	16.6	16.7	16.4	14.8	14.6	14.3	14.4	13.8
Power and pumping:										
Operating labor	3.8	3.8	4.0	3.9	3.7	3.6	3.7	2.9	2.7	2.7
Maintenance	3.4	3.5	3.8	3.8	3.9	4.3	3.5	4.2	3.7	3.5
Power	11.0	11.5	10.9	10.7	10.2	9.9	9.6	10.7	10.5	10.3
Other	2.3	2.3	2.3	2.5	2.4	2.2	2.2	2.2	2.1	2.5
Total power and pumping	20.5	21.1	21.0	20.9	20.2	20.0	19.0	20.0	19.0	19.0
Transmission and distribution:										
Operating labor	8.7	8.6	8.5	8.1	8.6	8.1	8.2	7.5	7.0	7.4
Maintenance	18.9	19.5	20.1	20.9	21.5	20.3	21.8	22.0	21.5	21.3
Other	1.7	1.4	1.9	2.3	1.1	1.1	1.9	1.0	1.8	1.5
Total transmission and distribution	29.3	29.5	30.5	31.3	31.2	29.5	31.9	30.5	30.3	30.2
Total operating expense	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 14. CINCINNATI WATER WORKS CAPITAL AND OPERATING COSTS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense	$5,310,156	$5,274,886	$5,615,223	$6,016,945	$6,183,047	$7,050,725	$7,277,491	$8,158,245	$8,594,868	$8,782,422
Capital expense:										
Depreciation	1,177,441	1,230,236	1,421,671	1,549,928	1,605,070	1,633,727	1,632,017	1,656,520	1,699,258	1,771,299
Interest expense	826,052	947,251	926,933	877,190	887,150	887,103	792,755	802,055	710,555	669,455
Total	7,313,650	7,452,373	7,963,827	8,444,063	8,665,267	9,571,465	9,702,263	10,616,820	11,004,681	11,223,176
Total cost/mil gal	228.10	225.41	236.14	247.19	249.56	264.41	261.39	278.45	290.14	294.54

TABLE 15. CINCINNATI WATER WORKS CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense ($)	5,310,156	5,274,886	5,615,223	6,016,945	6,183,047	7,050,725	7,277,491	8,158,245	8,594,868	8,782,422
Capital expense ($) (Interest, $)	2,033,494 (826,052)	2,177,487 (947,251)	2,348,604 (926,933)	2,427,118 (877,190)	2,492,220 (887,150)	2,520,740 (887,013)	2,424,772 (792,755)	2,458,575 (802,055)	2,409,813 (710,555)	2,440,754 (669,955)
Total	7,313,650	4,452,373	7,963,827	8,444,063	8,675,267	9,571,465	9,702,263	10,616,820	11,004,681	11,223,167
Operating expense as % of total	72.61	70.78	70.51	71.25	71.35	73.66	75.01	75.84	78.10	78.25
Capital expense as % of total	27.39	29.22	29.49	28.75	28.65	26.34	24.99	24.16	21.90	21.75

TABLE 16. CINCINNATI WATER WORKS LABOR COST ANALYSIS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Total payroll ($)	3,393,575	3,399,082	3,664,567	3,946,864	4,085,948	4,446,863	4,467,360	4,979,657	5,261,055	5,474,585
Total hours on payroll	1,110,032	1,116,220	1,102,892	1,120,980	1,148,588	1,141,448	1,115,744	1,094,229	1,071,476	1,046,724
Revenue-producing water ($/mil gal)	32,063	33,061	33,725	34,160	34,722	36,199	37,117	38,128	37,928	38,104
Total payroll metered ($/mil gal)	105.84	102.81	108.66	115.54	117.68	122.84	120.36	130.60	138.71	143.67
Total hours RPW ($/mil gal)	34.62	33.76	32.70	32.81	33.08	31.53	30.06	28.70	28.25	27.47
Average cost/man-hour	3.06	3.04	3.32	3.52	3.56	3.89	4.00	4.55	4.91	5.23
Capital/labor cost ratio	0.60	0.64	0.64	0.61	0.61	0.57	0.54	0.49	0.46	0.45

A reproduction cost was calculated using the historical costs, the Engineering News Record Building Cost Index (1913 = 100) for buildings and equipment, and the Engineering News Record Construction Cost Index (1903 = 100) for pipes and valves. A skilled labor cost factor was used to compute the Building Cost Index, and a common labor cost factor was used to compute the Construction Cost Index. After weighing these capital expenditures with the proper indices, a reproduction cost of $459 million was found for the current plant-in-service, which represents a 311% increase over the historical value. These capital expenditures include capital investment in a new treatment plant (Great Miami), which is expected to be operational soon. Derivation of a reproduction value facilitates examining the impact of inflation on capital cost and the current worth of capital's contribution to output. The computations discussed in this section are summarized in Table 17.

SYSTEM COSTS

With the cost data for the various functional areas discussed earlier, costs were allocated to specific treatment, transmission, storage, and pumping facilities in the system. A general cost was determined for distribution, interest, and overhead. Using costs based on 1973 dollars, and assuming a linear allocation of costs for a given area against capacity required to serve it, the facility costs ($/mil gal) associated with each service area, such as pumping and storage, were established as shown in parentheses in Figure 7.

The costs in the schematic diagram (Figure 7) can be related to the costs in Table 18 and 19. For example, the acquisition cost for water from the Ohio River, including depreciation of the facility and operating costs, is $16.70/mil gal (Figure 7). As a unit of water (mil gal) moves through each facility to another service area, the unit cost of moving it through that area is added to the cost of getting water to that area, thereby creating the incremental costs shown in Table 19. The facility and transmission costs are added to the costs of distribution, interest, and overhead to yield an average unit cost to serve that area. A service zone represents a customer service area and a demand point for water. For purposes of this analysis, an attempt was made to discriminate between the water demanded in a given distribution area and the water transmitted through the area into the next service zone.

PRICING ANALYSIS

The price of water ($/mil gal) for the top 10 users for 1973 in the Cincinnati Water Works service area is shown in Table 20. In the city, the Davison Chemical Company paid a low monthly rate of $87.54/mil gal and a high of $180.26/mil gal. These data are based on utilization of water for 1973, and on the rates shown in Tables 21 and 22.

TABLE 17. CINCINNATI WATER WORKS HISTORICAL AND REPRODUCTION COSTS OF PLANT-IN-SERVICE

Capital facility	Historical cost	Reproduction cost (1973-74 dollars)
Plant	$42,649,160	$146,981,272
Pipe	54,848,943	296,771,626
Misc. plant*	14,202,213	15,237,389
Total	111,700,315	458,990,286

* Capital expenditures that are not specifically identified.

TABLE 18. TRANSMISSION COSTS BETWEEN SERVICE AREAS ($/mil gal)*

	To									
From	A	B1	B2	C1a	C1b	C2	C3a	C3b	C4a	C4b
Treatment plant	$78.14	$75.43	---	$19.76	---	$28.93	$22.29	---	$24.98	---
Service area:										
B1	---	---	$60.26	---	---	---	---	---	---	---
C1a	---	---	---	---	$113.61	---	---	---	---	---
C3a	---	---	---	---	---	---	---	$39.45	---	---
C4a	---	---	---	---	---	---	---	---	---	$50.03

* See Figure 9 for geographic locations of service areas.

TABLE 19. CINCINNATI WATER WORKS COST, CONSUMPTION, AND REVENUE BY AREA, (1973)

Area	Incremental cost ($/mil gal)	Total ($/mil gal)*	RPW (gallons)	Revenue ($)
A	251.19	404.50	190,150	76,915.68
B1	183.55	336.86	629,050	211,901.78
B2	324.29	477.60	339,991	162,379.70
C1a	109.68	262.99	6,796,811	1,787,493.30
C1b	291.58	444.89	290,806	129,376.68
C2	119.49	272.80	9,667,159	2,637,200.90
C3a	122.23	275.54	3,784,174	1,042,691.30
C3b	193.11	346.42	3,873,248	1,341,770.50
C4a	111.25	264.56	7,640,334	2,021,326.70
C4b	226.29	379.60	4,859,095	1,844,512.40
Total	---	---	38,070,818	11,255,568.94

* Includes distribution ($50.52), interest ($17.57), and overhead ($85.22).

TABLE 20. CINCINNATI WATER WORKS WATER COST FOR 10 MAJOR USERS

Major user	High or low month	Month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Location	Cost zone
City of Norwood	High	11	163.6	$48,112.24	$294.12	Suburb	C2
	Low	3	112.4	33,046.20	294.12		
Hilton Davis	High	2	56.1	9,464.44	168.83	City	C1a
	Low	1	33.1	5,773.96	174.67		
Sun Chemical	High	9	50.9	8,642.84	169.87	City	C3a
	Low	11	32.0	5,612.72	175.44		
Procter and Gamble	High	7	46.1	14,232.55	308.70	Suburb	C3a
	Low	2	30.6	9,829.27	321.12		
Davison Chemical	High	7	62.3	5,457.40	87.54	City	C2
	Low	12	23.0	4,154.56	180.26		
Metropolitan Sewer	High	12	33.2	5,822.88	175.19	City	C4a
	Low	6	19.6	3,638.88	185.44		
Cincinnati Milacron	High	7	34.8	6.097.44	175.07	City	C2
	Low	4	22.2	4,166.40	187.95		
Kroger Company	High	7	24.0	7.538.95	313.54	Suburb	C1a
	Low	8	16.6	5,447.98	328.26		
Kroger Company	High	7	22.9	4,167.12	181.90	City	C4a
	Low	12	13.2	2,607.72	197.73		
E. Kahn's Sons	High	5	23.3	4,230.68	181.67	City	C4a
	Low	11	14.2	2,778.44	195.17		

TABLE 21. CINCINNATI WATER WORKS METER RATES (APRIL 1, 1969)

Criteria		Minimum charges					
		Inside Cincinnati		Outside Cincinnati in Hamilton and Clermont Counties		Butler and Warren Counties	
Meter size (in)	Family units (number)	Monthly	Quarterly	Monthly	Quarterly	Monthly	Quarterly
5/8	1	$2.50	$4.50	$5.00	$9.00	$5.75	$10.35
3/4	2 - 3	2.80	5.40	5.60	10.80	6.45	12.40
1	4 - 5	3.50	7.50	7.00	15.00	8.05	17.25
1½	6 - 12	4.50	10.50	9.00	21.00	10.35	24.15
2	13 - 20	7.00	18.00	14.00	36.00	16.10	41.40
3	21 - 50	9.00	24.00	18.00	48.00	20.70	55.20
4	55 - 115	12.00	33.00	24.00	66.00	27.00	75.00
6	116 - 250	25.00	75.00	50.00	150.00	57.00	170.00
8	over 250	35.00	105.00	70.00	210.00	80.00	240.00
10		40.00	120.00	80.00	240.00	92.00	270.00
12		40.00	120.00	80.00	240.00	92.00	270.00

TABLE 22. CINCINNATI WATER WORKS MONTHLY AND QUARTERLY COMMODITY CHARGES (cents/100 cu ft)

Per month	Per quarter	Inside Cincinnati	Outside Cincinnati in Hamilton and Clermont Counties	Butler and Warren Counties
1,000 - 60,000 cu ft	2,000 - 180,000 cu ft	20	35	40
50,000 - 1 million cu ft	180,000 - 3 million cu ft	16	28	32
Over 1 million cu ft	Over 3 million cu ft	12	21	24

The lowest cost for water delivered to a service area was for area Cla ($262.99/mil gal). Cost areas defined in this report and the 10 major users are shown in Figure 9, which allows for easy visual comparison between the data in Figure 7 and Table 20. These data are summarized in Table 23, which compares the cost and revenues from various levels of water used for the 10 major users in the water works billing area. Many of the major users do not meet the cost of supplying water to them.

Table 23 (column 2) presents a cost comparison based on the assumption that each of the costs in the categories of acquisition, treatment, transmission and distribution, power and pumping, support services, and capital can be based on a cost/mil gal basis. Such an assumption might be questioned, particularly as it relates to support services. An alternate means of cost allocation to the 10 largest users may be generated through adjustment of support services cost/mil gal to overhead cost/customer.

Total support services is $2.8 million, which, when divided by total metered water, gives a unit cost of $72.60/mil gal. The remaining $12.62/mil gal included in the $85.22 support services cost refers to miscellaneous capital and operating expenditures not counted in the incremental costs for each service area.

The $72.60/mil gal cost can be reallocated on a per-customer basis, since there are 186,910 quarterly accounts and 1,533 monthly accounts. Customers billed monthly require three times as many meter readings, yielding a total of 191,509 equivalent quarterly accounts. Support services cost per quarterly customer is therefore $14.44.

For the 10 largest users (which are monthly accounts), the support services cost is $43.32/customer (three times that for the quarterly customers). This adjusted overhead cost is then added to the incremental, interest, adquisition, treatment, distribution, transmission, and miscellaneous support services cost for each zone. Total costs to supply the 10 largest customers are shown in column 3 of table 23.

The adjusted cost approach lowers the costs for the 10 major users, but it raises the proportion of support services that the other users must bear. Nevertheless, the same users that pay less than cost now (column 2, Table 23) would continue to pay less than cost (column 3). Both approaches reveal an interesting picture of costs and the way they vary throughout the Cincinnati Water Works service area.

The average unit costs for all water supplied during the most recent year studied are as follows:

	$/mil gal
Support services	85
Acquisition	17
Treatment	36
Distribution	139
Interest	18
Total	295

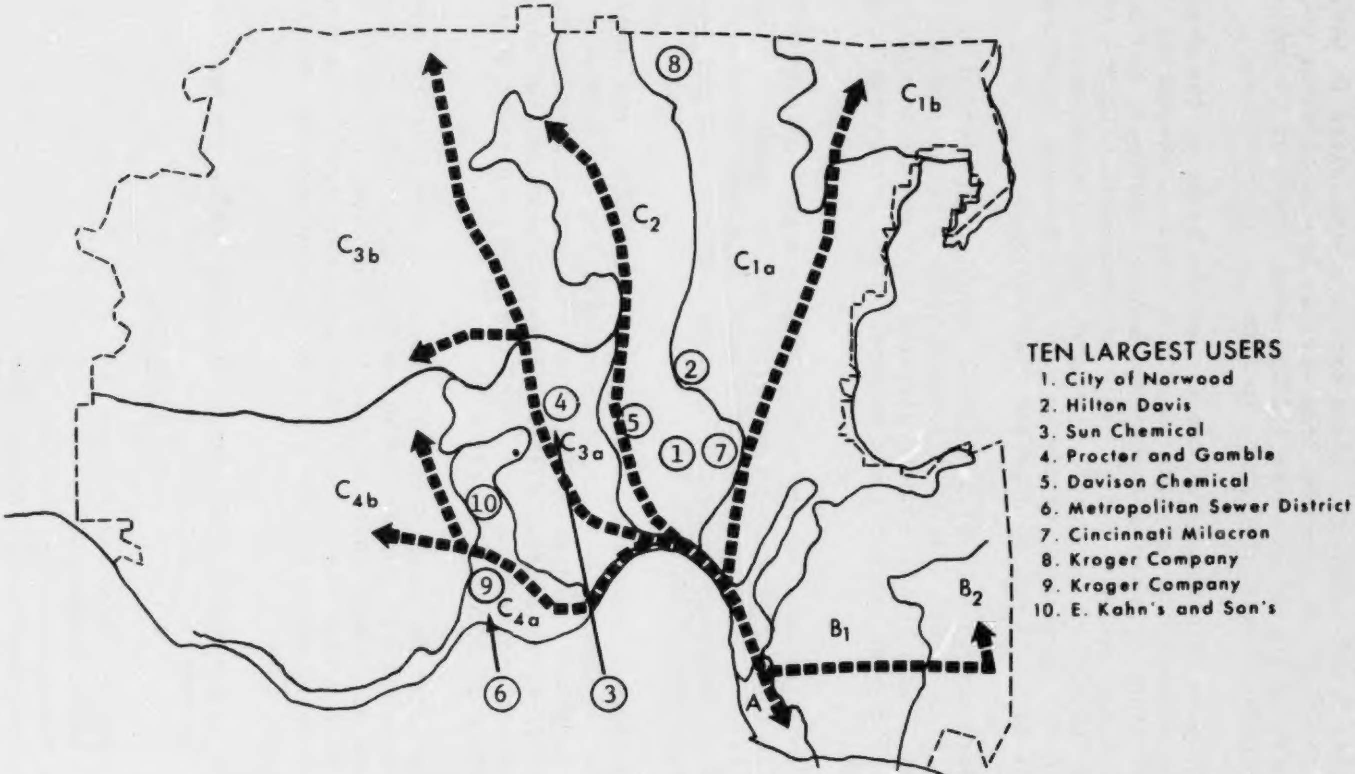

C1b
C2
C1a
C3b
C3a
C4b
C4a
A
B1
B2
TEN LARGEST USERS
1. City of Norwood
2. Hilton Davis
3. Sun Chemical
4. Procter and Gamble
5. Davison Chemical
6. Metropolitan Sewer District
7. Cincinnati Milacron
8. Kroger Company
9. Kroger Company
10. E. Kahn's and Son's

Figure 9. Location of 10 major users within the Cincinnati Water Works service area, B1, B2, C1a, etc. denote various distribution areas within the system.

TABLE 23. ACTUAL PRICE VERSUS COST COMPARISONS FOR TEN MAJOR USERS IN CINCINNATI WATER WORKS SERVICE AREA ($/mil gal)

Major user	Price[*]	Cost[+]	Adjusted cost[+]
Norwood	$294.12	$272.80	$243.52
Hilton Davis	168.83 175.67	262.99	233.71
Sun Chemical	169.87 175.44	275.54	246.26
Procter and Gamble[‡]	308.70 321.12	275.54	246.26
Davison Chemical	87.54 180.26	272.80	243.57
Metropolitan Sewer	175.19 185.44	264.56	235.28
Cincinnati Milacron	175.07 187.95	272.80	243.52
Kroger Company (Suburb)[‡]	313.54 328.26	262.99	233.71
Kroger Company (City)	181.90 197.73	264.56	235.28
E. Kahn's Sons	181.67 195.17	264.56	235.28

[*] Wherever two values are presented, one represents the high and the other the low bill in $/mil gal for 1973-74.

[+] These values were calculated on an average cost basis and as such do not reflect potential economies of scale that result from having large users in the system.

[‡] Suburban users are charged at a higher rate to allow for expansion into Hamilton County.

SECTION 6

KANSAS CITY, MISSOURI, WATER DEPARTMENT

The Kansas City, Missouri, Water Department provides treated water to citizens and industry located in Kansas City. The retail service area of the Kansas City Water Department served approximately 515,000 people in 1973. Population trends in the area have shown a relatively slow increase during the past 10 years. Most of the increase in residential population has been in fringe areas of the city. Some basic facts about the system are shown in Table 24.

WATER SUPPLY SERVICE AREA

The Kansas City Water Department provides water on a retail basis to all classes of customers within the service area (Figure 10). This treated water is supplied primarily to all users within the incorporated limits of Kansas City. In addition to these areas, water is sold to other water utilities such as the Raytown Water Company, Lee Summit, Belton, and other water distributors servicing areas outside of Kansas City.

ORGANIZATION

The Kansas City Water Department operates as a department of the Kansas City government. Basically, the department provides only the service of delivering potable water to its users; however, the director of the water supply department and the director of the pollution control department (which includes sewage treatment) report to the same person. Some mixing of activities therefore occurred and had to be separated to identify costs associated with water production.

Some reorganization of the management structure occurred in the 2 years before the study began. The present organization shown in Figure 11 is made up of five divisions that report to the Director for Water Supply.

ACQUISITION

Raw water comes primarily from the Missouri River and is delivered directly to a treatment plant near the intake where all raw water is treated. A well field capable of producing 25 MGD is located near the intake facility and provides some of the raw water for the Kansas City system. The purpose of the well water, however, is primarily to assist in treatment processes and temperature control during the winter. An adequate amount of raw water

TABLE 24. KANSAS CITY, MISSOURI, WATER DEPARTMENT, BASIC FACTS*

Item	Amount
Population (1973):	
SMSA	1,295,000
County	813,900
Retail service area	515,000
Area of retail service area (sq miles)	316
Recognized customer classes (No. of accounts):	
Industrial and commercial	13,719
Residential	116,417
Suburban	1,429
Flat-rate customers	None
Percent metered	100%
Purchased water	None
Source water	10% Well - 90% River
Pipe in system (miles)	1,912.1
Elevation of treatment plant (ft above mean sea level)	754
Elevation of service area (min-max, ft)	722/1188
Revenue-producing water (mil gal)	26,856
Treated water (pumpage from treatment plants, mil gal)	35,150
Max day/max hour (July 4, 1974, MGD)	179/238

* All data except population are for 1974.

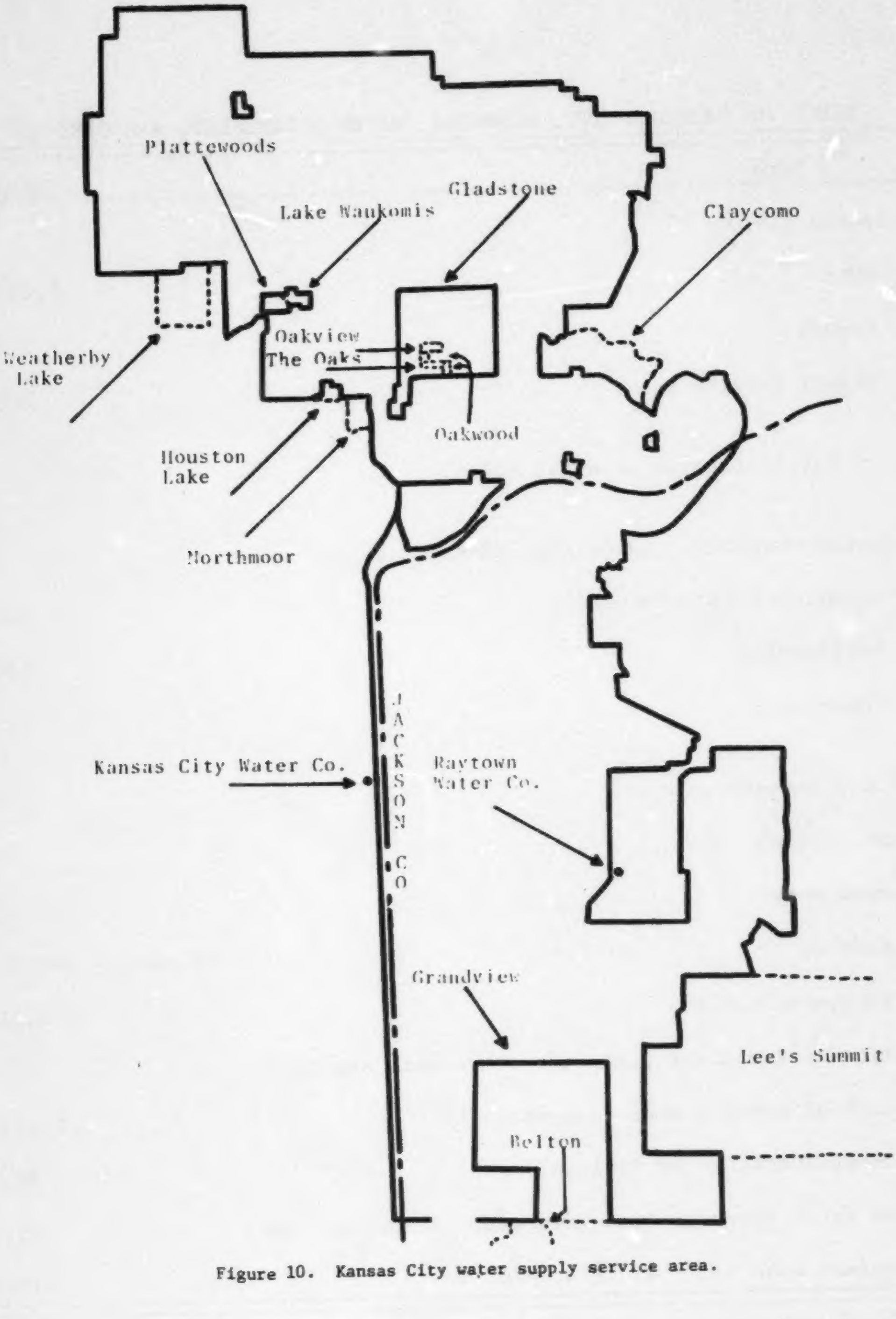

Plattewoods
Lake Waukomis
Gladstone
Claycomo
Weatherby Lake
Oakview
The Oaks
Oakwood
Houston Lake
Northmoor
JACKSON CO
Kansas City Water Co.
Raytown Water Co.
Grandview
Lee's Summit
Belton

Figure 10. Kansas City water supply service area.

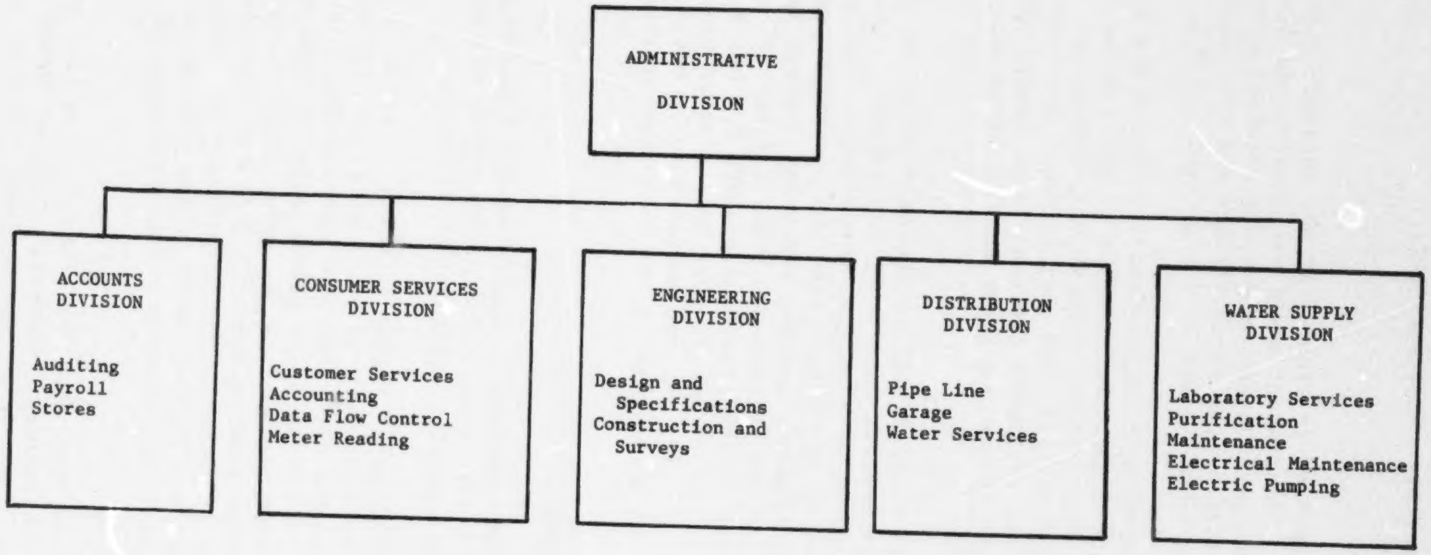

ADMINISTRATIVE DIVISION
ACCOUNTS DIVISION
Auditing
Payroll
Stores
CONSUMER SERVICES DIVISION
Customer Services
Accounting
Data Flow Control
Meter Reading
ENGINEERING DIVISION
Design and Specifications
Construction and Surveys
DISTRIBUTION DIVISION
Pipe Line
Garage
Water Services
WATER SUPPLY DIVISION
Laboratory Services
Purification
Maintenance
Electrical Maintenance
Electric Pumping

Figure 11. Kansas City Water Department organizational structure.

intake facility near the entrance to the treatment plant delivers water directly from the river to the treatment facility.

TREATMENT

All raw water for Kansas City is treated in one facility located on the bank of the Missouri River. The present plant was constructed during the mid-twenties and put into use in 1928 with a pumping capacity of 100 MGD. A vast expansion program, started in the early fifties and completed in 1958, increased the rated capacity of the plant to its present 210 MGD.

Though the plant is housed in a single facility, there are actually three separate treatment facilities, each capable of functioning independently. The treatment plant performs four primary functions: softening, sterilization, taste and odor control, and coagulation. The water goes through five stages during the treatment process: four basins and a set of filters. Chemicals are added before and after each of these stages (Figure 12).

Physical, chemical, and bacteriological characteristics of the raw water from the Missouri River vary greatly on a daily and seasonal basis, depending on numerous factors such as rainfall, temperature, flow rates, and the character of waste material discharged into the river upstream. Daily tests are made of raw water samples, and the treatment process is modified as needed for changing conditions. Tests are made on finished water samples to assure that the objectives of the treatment process are met at all times. When the water leaves the filter basin, it goes into a large underground clear well with a capacity of 7 mil gal and is ready to be moved into the transmission and distribution system, which has much greater storage capacity.

TRANSMISSION AND DISTRIBUTION

The distribution system consists of approximately 1,912 miles of pipe in the ground, ranging from the 96-in. mains leading from the treatment facility to the 2-in. mains used for distribution to homes.

The terrain served elevations ranging from 722 to 1,188 ft above sea level; therefore, it is not necessary to boost water to high elevations. But it is necessary to transmit the water over considerable distances from the one treatment plant. Transmission is accomplished by both high- and low-head pumps. To the north and west of the water plant, water is transmitted by high pressure pumps feeding directly into the distribution system and delivering water under pressure to the consumers. The Waukomis pumping station boosts the pressure and flow of water in the extreme northern portion of the delivery system. This station boosts less than 2% of the water used by consumers.

Pumping to the south is through a low pressure flow line that delivers water to a 35-mil gal ground storage reservoir at Turkey Creek and into a 17-mil gal ground storage reservoir at East Bottoms. Both of these storage

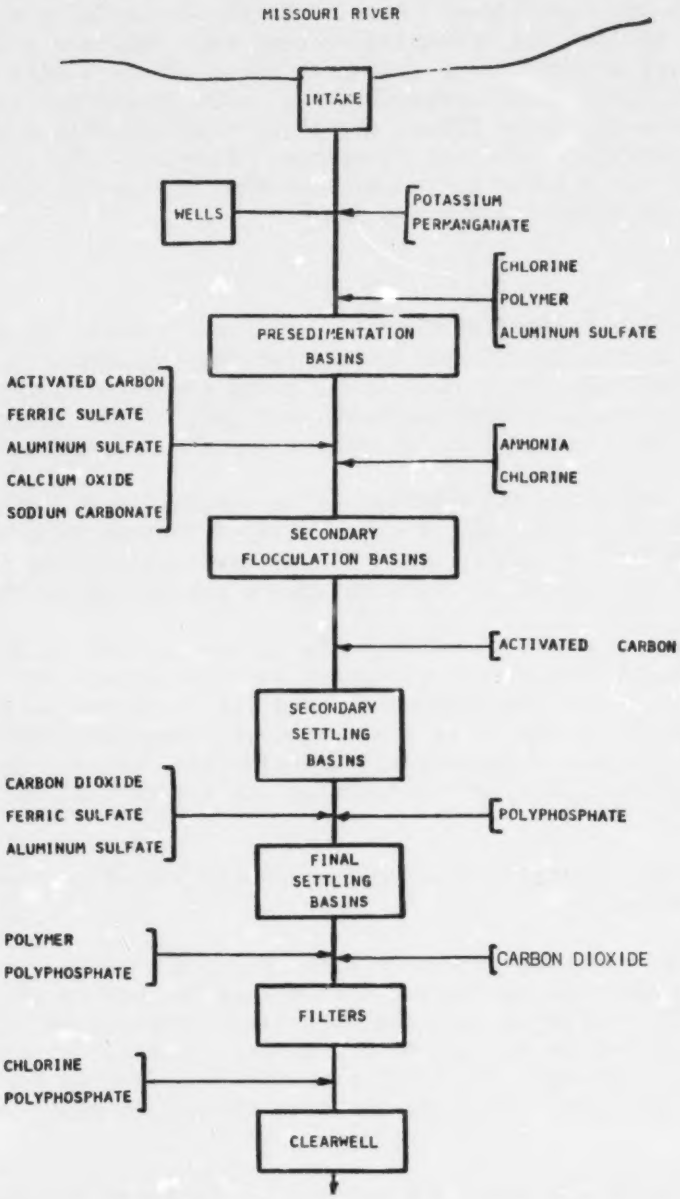

MISSOURI RIVER
INTAKE
WELLS
POTASSIUM PERMANGANATE
CHLORINE
POLYMER
ALUMINUM SULFATE
PRESEDIMENTATION BASINS
ACTIVATED CARBON
FERRIC SULFATE
ALUMINUM SULFATE
CALCIUM OXIDE
SODIUM CARBONATE
AMMONIA
CHLORINE
SECONDARY FLOCCULATION BASINS
ACTIVATED CARBON
SECONDARY SETTLING BASINS
CARBON DIOXIDE
FERRIC SULFATE
ALUMINUM SULFATE
POLYPHOSPHATE
FINAL SETTLING BASINS
POLYMER
POLYPHOSPHATE
CARBON DIOXIDE
FILTERS
CHLORINE
POLYPHOSPHATE
CLEARWELL

Figure 12. Kansas City Water Department treatment plant schematic.

facilities have high pressure pumps that move the water into the transmission and distribution system. Approximately 65% of the water consumed by customers is delivered directly by these two pumping stations, which also delivers water to two ground storage reservoirs located further south in the system at Waldo and Blue Ridge. Each of these reservoirs has a storage capacity of 10 mil gal and a pumping station that delivers the water under pressure into the distributions system at the southern limits of the service area. Table 25 shows the storage capacity, both ground and elevated, within the Kansas City system. As shown, there are approximately 3 mil gal of elevated storage throughout the entire system. This elevated storage assists in maintaining pressure within the distribution system but the main source of pressure comes directly from the pumps.

COST ANALYSIS

Figure 13 illustrates the growth in consumer demand for water from 1964 through 1974. A wide discrepancy exists between the amount of water treated and the amount billed. This problem was being analyzed by the water department at the time the data were gathered, and part of the difference (RPW for 1973 and 1974) then appeared to be the result of a computer problem.

Data were collected and reported using standard cost categories, as shown in Tables 26 through 28. Because a major portion of the operating budget was expended for labor, Table 29 was developed to examine costs associated with the operation and maintenance activities of the department.

The cost/man-hour increased over the 10-year period by 98%, whereas the total payroll hours required to produce a billion gallons of RPW decreased by 9% (Table 29). Thus the operating costs for producing water did not increase as rapidly as the labor cost/man-hour. However, when it is no longer possible to gain increased efficiencies with respect to manpower, the operating costs will start to increase at a rate that is at least equal to the labor cost.

Operating and capital costs for the 10-year period of the analysis are summarized in Table 30.

Capital and operating expense ratios (Table 31) provide a comparison of expenditures made for operations and capital in each of the 10 years under study. The operating expenses shown as a total value in the table are the expenses incurred in the normal day-to-day operation of the system. The capital expenses represent the total periodic expenditures for major equipment items and facilities plus the interest charged on money borrowed for that purpose.

A comparison of the operating and capital expenses as a percent of the total shows that in the Kansas City Water Department, more expenses are associated with operations than with capital. Over the 10-year period, this trend has continued and is primarily a result of the continued increase in the cost of items necessary for operation, such as increasing salaries. During the same time period, no major capital costs were incurred; therefore, the expenditure ratio shifted from 69% operating:31% capital in

TABLE 25. KANSAS CITY WATER DEPARTMENT SYSTEMS STORAGE

Type of storage	Overflow elevation (ft above sea level datum)	Capacity (mil gal)
Elevated storage tanks:		
KC1	1174	.25
North (out of service)	1124	.15
North (out of service)	1124	.15
East	1120	2.00
Ruskin	1189	.40
150 Highway	1152	.06
House service	958	.07
Total elevated storages	---	3.08
	Ground level elevation (ft above sea level datum)	Capacity (mil gal)
Ground storage reservoirs:		
Clear Well	754	7
Turkey Creek	764	35
East Bottoms	752	17
Waldo	1008	10
Blue Ridge	1019	10
Total ground storage	---	79

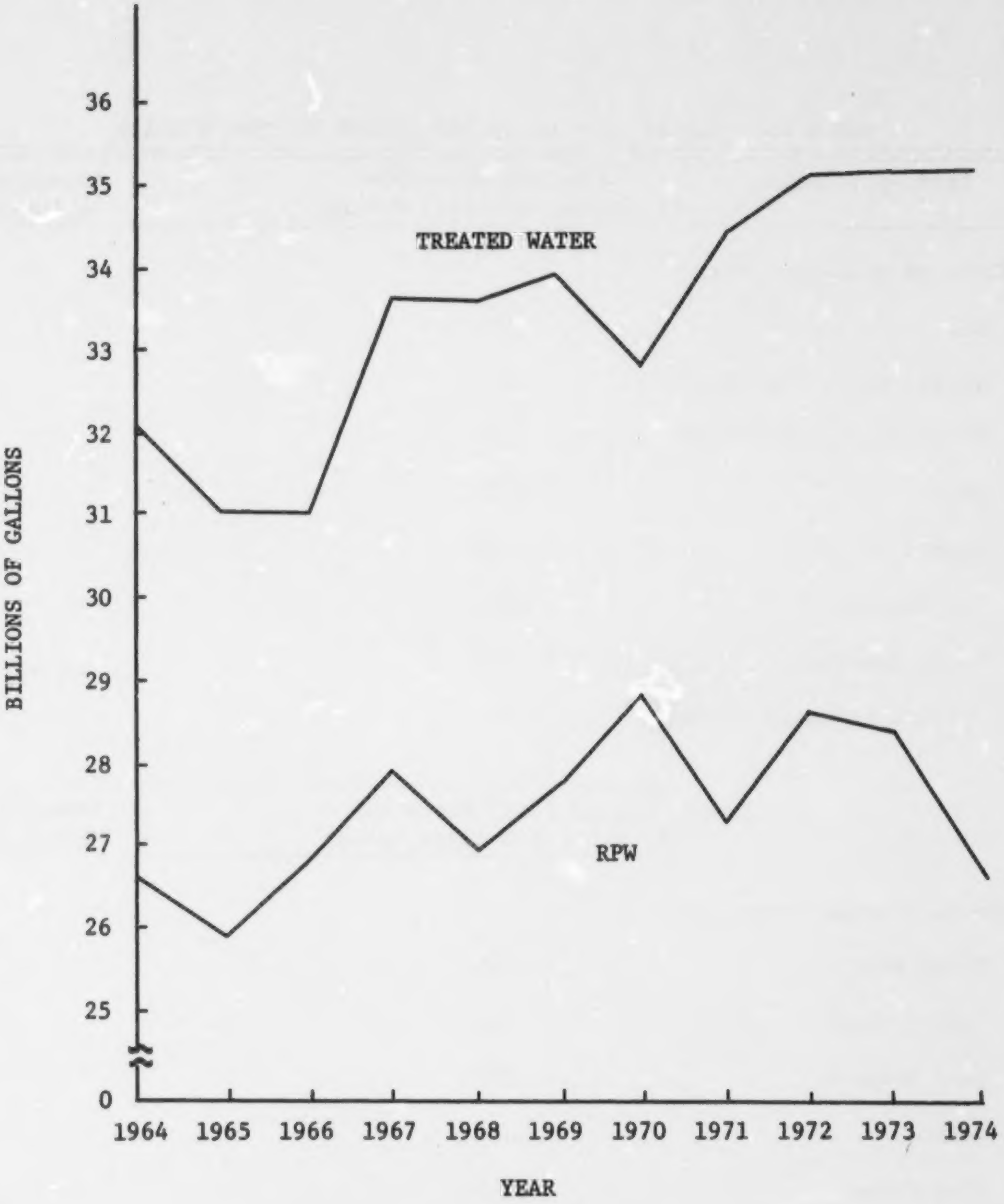


Figure 13. Kansas City water flow: treated water versus RPW.

TABLE 26. KANSAS CITY WATER DEPARTMENT ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$ 777,760	$ 892,396	$ 860,750	$ 953,346	$1,243,758	$1,308,126	$1,518,099	$1,477,868	$1,597,632	$1,609,870
Accounting and collection	628,155	738,702	802,054	1,128,566	1,250,998	1,467,475	1,390,970	1,347,694	1,445,082	1,410,436
Service	278,532	332,123	369,497	434,332	484,127	486,498	549,484	523,104	543,821	544,270
Other	152,603	99,154	112,638	134,914	169,385	155,301	107,146	231,287	228,826	221,808
Total support services	1,837,050	2,062,375	2,144,939	2,651,158	3,148,268	3,417,400	3,565,699	3,579,953	3,815,361	3,786,384
Acquisition:										
Operating labor	33,818	41,574	43,192	51,824	59,821	63,369	65,459	57,068	71,119	76,485
Maintenance	11,997	6,519	11,315	25,322	32,981	26,332	31,330	34,164	36.749	28,677
Power	152,703	146,082	159,578	159,099	168,077	168,537	179,968	199,767	200,370	216,147
Other	34,162	36,244	36,683	40,843	45,861	59,734	60,311	59,210	57,124	53,068
Total acquisition	232,680	230,419	250,768	277,087	306,740	317,972	337,068	350,210	365,362	374,378
Treatment:										
Laboratory	57,755	69,717	80,672	74,728	112,268	136,431	141,653	179,765	192,829	196,290
Operating labor	125,490	139,192	134,802	173,343	181,001	190,719	176,840	185,954	220,294	228,645
Chemicals	492,523	531,327	576,501	523,917	488,972	673,105	705,175	799,833	992,883	959,156
Maintenance	157,316	139,655	166,376	192,978	222,492	180,958	168,861	180,960	202,370	262,294
Other	184,811	206,096	236,433	231,513	285,859	353,555	369,907	369,630	274,674	352,140
Total treatment	1,017,895	1,085,986	1,194,784	1,196,479	1,290,592	1,534,768	1,562,436	1,716,142	1,883,050	1,998,525
Power and pumping:										
Operating labor	138,864	170,710	177,356	212,800	245,635	260,207	268,789	234,335	292,030	314,064
Maintenance	49,264	26,768	46,461	103,975	135,428	108,125	128,647	140,284	150,889	117,756
Power	627,029	599,845	655,260	653,293	690,160	692,050	738,988	820,287	822,761	887,546
Other	140,278	148,825	150,628	167,708	188,314	245,278	247,648	243,128	234,563	217,910
Total power and pumping	955,435	946,148	1,029,706	1,137,777	1,259,537	1,305,661	1,384,072	1,438,033	1,500,253	1,537,275
Transmission and distribution:										
Operating labor	79,277	77,593	95,026	99,400	117,922	129,439	125,080	171,432	175,793	185,499
Maintenance	364,533	425,728	493,108	505,435	560,517	738,226	747,918	785,554	717,772	773,622
Other	139,731	126,140	140,908	163,829	199,586	200,004	240,385	238,750	258,166	245,815
Total transmission and distr.	583,541	629,461	729,042	768,664	878,025	1,067,669	1,113,383	1,195,736	1,151,731	1,204,936
Total operating cost	4,626,601	4,954,389	5,349,239	6,031,165	6,883,162	7,643,470	7,962,658	8,280,074	8,715,757	8,901,498

TABLE 27. KANSAS CITY WATER DEPARTMENT UNIT OPERATING COSTS ($/MIL GAL RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$ 29.68	$ 33.07	$ 30.67	$ 35.13	$ 44.68	$ 45.28	$ 55.34	$ 51.44	$ 56.71	$ 59.95
Accounting and collection	23,97	27.37	28.58	41.58	44.94	50.79	50.71	46.91	51.30	52.52
Service	10.63	12.31	13.17	16.00	17.39	16.84	20.03	18.21	19.30	20.27
Other	5.82	3.67	4.01	4.97	6.08	5.38	3.91	8.05	8.12	8.26
Total support services	70.11	76.43	76.43	97.68	113.10	118.28	129.98	124.60	135.44	140.99
Acquisition:										
Operating labor	1.29	1.54	1.54	1.91	2.15	2.19	2.39	1.99	2.52	2.85
Maintenante	0.46	0.24	0.40	0.93	1.18	0.91	1.14	1.19	1.30	1.07
Power	5.83	5.41	5.69	5.86	6.04	5.83	6.56	6.95	7.11	8.05
Other	1.30	1.34	1.31	1.50	1.65	2.07	2.20	2.06	2.03	1.98
Total acquisition	8.88	8.54	8.94	10.21	11.02	11.01	12.29	12.19	12.97	13.94
Treatment:										
Laboratory	2.20	2.58	2.87	2.75	4.03	4.72	5.16	6.26	6.84	7.31
Operating labor	4.79	5.16	4.80	6.39	6.50	6.60	6.45	6.47	7.82	8.51
Chemicals	18.80	19.69	20.54	19.34	17.57	23.30	25.71	27.84	35.24	35.71
Maintenance	6.00	5.18	5.93	7.1[illegible]	7.99	6.26	6.16	6.30	7.18	9.77
Other	7.05	7.64	8.43	8.[illegible]	10.27	12.24	13.48	12.86	9.75	13.11
Total treatment	38.85	40.24	42.56	44.08	46.36	53.12	56.96	59.73	66.84	74.42
Power and pumping:										
Operating labor	5.30	6.33	6.32	7.84	8.82	9.01	9.80	8.16	10.37	11.69
Maintenance	1.88	0.99	1.66	3.83	4.87	3.74	4.69	4.88	5.36	4.38
Power	23.93	22.23	23.35	24.07	24.79	23.95	26.94	28.55	29.21	33.05
Other	5.35	5.52	5.37	6.18	6.76	8.49	9.03	8.46	8.33	8.11
Total power and pumping	36.46	35.06	36.69	41.92	45.25	45.19	50.45	50.05	53.26	57.24
Transmission and distribution:										
Operating labor	3.03	2.88	3.39	3.66	4.24	4.48	4.56	5.97	6.24	6.91
Maintenance	13.91	15.78	17.57	18.62	20.14	25.55	27.26	27.34	25.48	28.81
Other	5.33	4.67	5.02	6.04	7.17	6.92	8.76	8.31	9.16	9.15
Total transmission and distribution	22.27	23.33	25.98	28.32	31.54	36.95	40.59	41.62	40.88	44.87
Total operating cost	176.56	183.60	190.62	222.21	247.27	264.55	290.27	288.18	309.39	331.45

The above figures are not additive. They are obtained by dividing yearly mil gal RPW into the annual costs shown in the preceding table.

TABLE 28. KANSAS CITY WATER DEPARTMENT OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	16.81	18.01	16.09	15.81	18.07	17.11	19.07	17.84	18.33	18.09
Accounting and collection	13.58	14.91	14.99	18.71	18.17	19.20	17.47	16.28	16.57	15.84
Service	6.02	6.70	6.91	7.20	7.03	6.36	6.90	6.32	6.24	6.11
Other	3.30	2.00	2.11	2.24	2.46	2.03	1.35	2.79	2.63	2.49
Total overhead	39.71	41.62	40.10	43.96	45.74	44.71	44.79	43.23	43.77	42.54
Acquisition:										
Operating labor	0.73	0.84	0.81	0.86	0.87	0.83	0.82	0.69	0.82	0.86
Maintenance	0.26	0.13	0.21	0.42	0.48	0.34	0.39	0.41	0.42	0.32
Power	3.30	2.95	2.98	2.64	2.44	2.20	2.26	2.41	2.30	2.43
Other	0.74	0.73	0.69	0.68	0.67	0.78	0.76	0.72	0.66	0.60
Total acquisition	5.03	4.65	4.69	4.59	4.46	4.16	4.23	4.23	4.20	4.21
Treatment:										
Laboratory	1.25	1.41	1.51	1.24	1.63	1.78	1.78	2.17	2.21	2.21
Operating labor	2.71	2.81	2.52	2.87	2.63	2.50	2.22	2.25	2.53	2.57
Chemicals	10.65	10.72	10.78	8.69	7.10	8.81	8.86	9.66	11.40	10.78
Maintenance	3.40	2.82	3.11	3.20	3.23	2.37	2.12	2.19	2.32	2.95
Other	3.99	4.16	4.42	3.84	4.15	4.63	4.65	4.46	3.15	3.96
Total treatment	22.00	21.92	22.33	19.84	18.75	20.08	19.62	20.73	21.61	22.45
Power and pumping:										
Operating labor	3.00	3.45	3.32	3.53	3.57	3.40	3.38	2.83	3.35	3.53
Maintenance	1.06	0.54	0.87	1.72	1.97	1.41	1.62	1.69	1.73	1.32
Power	13.55	12.11	12.25	10.83	10.03	9.05	9.28	9.91	9.44	9.97
Other	3.03	3.00	2.82	2.78	2.74	3.21	3.11	2.94	2.69	2.45
Total power and pumping	20.65	19.10	19.25	18.86	18.30	17.08	17.38	17.37	17.21	17.27
Transmission and distribution:										
Operating labor	1.71	1.57	1.78	1.65	1.72	1.69	1.57	2.07	2.02	2.08
Maintenance	7.88	8.59	9.22	8.38	8.14	9.66	9.39	9.49	8.23	8.69
Other	3.02	2.55	2.63	2.72	2.90	2.62	3.02	2.88	2.96	2.76
Total transmission and distribution	12.61	12.71	13.63	12.75	12.76	13.97	13.98	14.44	13.21	13.53
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 29. KANSAS CITY WATER DEPARTMENT LABOR COST ANALYSIS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	2,627,096	2,707,386	2,834,801	3,335,272	3,864,478	4,276,038	4,572,337	4,486,488	4,577,926	4,865,085
Total hours on payroll	1,219,867	1,206,749	1,167,368	1,276,910	1,359,372	1,371,570	1,309,498	1,153,979	1,113,292	1,143,839
RPW (mil gal)	26,204	26,985	28,063	27,141	27,837	28,892	27,432	28,732	28,171	26,856
Total payroll/mil gal ($)	100.26	100.33	101.01	122.89	138.82	148.00	166.68	156.15	162.51	181.16
Total hours/mil gal	46.55	44.72	41.60	47.05	48.83	47.47	47.74	40.16	39.52	42.59
Average cost/man-hour ($)	2.15	2.24	2.43	2.61	2.84	3.12	3.49	3.89	4.11	4.25

TABLE 30. KANSAS CITY WATER DEPARTMENT CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	4,626,004	4,954,389	5,349,239	6,031,165	6,883,161	7,643,472	7,962,659	8,280,075	8,715,758	8,901,496
Depreciation, amortization ($)	1,008,700	1,042,635	1,055,788	1,065,576	1,098,210	1,117,895	1,156,777	1,202,328	1,263,516	1,315,193
Other (interest) ($)	1,063,760	1,067,192	981,434	939,797	1,061,401	1,207,367	1,519,028	1,456,258	1,406,804	1,351,320
Total cost ($)	6,699,064	6,507,351	7,386,461	8,036,538	9,042,772	9,968,733	10,638,464	10,938,661	11,386,078	11,568,009
Unit cost ($/mil gal RPW)	255.65	241.15	263.21	296.10	324,84	345,03	387.82	380.71	404.18	430.74

TABLE 31. KANSAS CITY WATER DEPARTMENT CAPITAL VERSUS OPERATING EXPENSES RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	4,626,604	4,954,389	5,349,239	6,031,165	6,883,161	7,643,472	7,962,659	8,289,075	8,715,758	8,901,496
Capital expense ($)	2,072,460	2,109,827	2,037,221	2,005,373	2,159,611	2,325,261	2,675,805	2,658,586	2,670,320	2,666,513
Total expense ($)	6,699,064	7,064,216	7,386,460	8,036,538	9,042,772	9,968,733	10,638,464	10,938,661	11,386,078	11,568,009
Operating expense as % of total	69.06	70.13	72.42	75.05	76.17	76.67	74.85	75.70	76.55	76.95
Capital expense as % of total	30.94	29.87	27.58	24.95	23.83	23.33	25.15	24.30	23.45	23.05

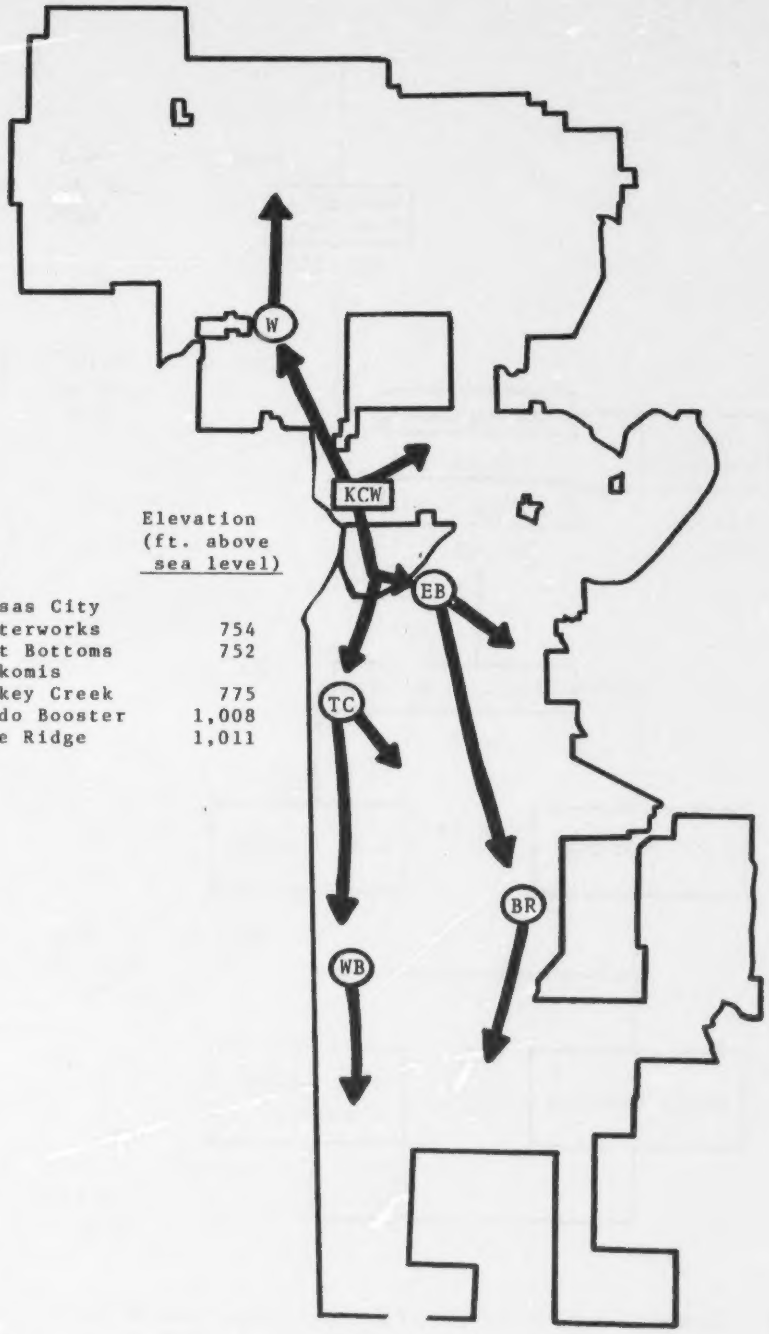
1965 to 77% operating:23% capital in 1974.

The Kansas City system is relatively old; therefore, the capital depreciated was expended when costs were significantly lower than at present. On the other hand, the operating expenses are in current dollars. This ratio will change whenever capital investments are made by the utility. For example, at some time in the future, major capital expenditures may be required at the treatment facility to meet increasing demands. When this occurs, the ratio of capital expense to operating expense will increase significantly.

SYSTEM COSTS

Examination of the costs on a functional basis is only a part of the total picture. Since the purpose of the water utility is to deliver water to customers, it is important to be able to present the costs in such a way that they relate to the delivery of water to the demand point within the distribution system. The functional categories, both operating and capital, should therefore be reaggregated and assigned to the physical components of the water delivery system. This section contains such a cost analysis of the water supply system.

To analyze the cost of water as it moves from acquisition to treatment and on to the consumer, it is necessary to identify the capital and operating costs of the system components. Figure 14 shows the location of the Kansas City Water Department facilities, and Figure 15 is a schematic diagram showing operating and capital costs for each of the major system components. A linear assumption is made that allows costs/mil gal to be added as water moves from one component of the system to another. For example, the cost of acquiring water from the Missouri River and moving it to the treatment plant is \$15.28/mil gal. The cost of treating the water from the time it arrives at the treatment plant until it is pumped out is \$81.98/mil gal. Two types of pumping occur out of the treatment plant: high-pressure pumping into the distribution system to the northwest, and low pressure flowline pumping to the south, toward the Turkey Creek and the East Bottoms storage and pumping facilities. Farther to the south, flowline pumping costs \$16.87/mil gal, with an additional operating capital cost of the flowline amounting to \$1.53. This moves the water to the pumping stations, which perform the function of high-pressure pumping into the distribution system. This high pressure pumping costs \$38.41. Adding these costs together yields a total incremental cost for providing water to service Zone 3 of \$163.19/mil gal (see Table 32). Added to the incremental costs are those for distribution, interest, and support services. Distribution costs are calculated on the assumption that these costs on a mil gal basis are constant throughout the system; therefore, the total capital and operating cost for distribution is divided by the number of gallons of RPW in the year under consideration, yielding a figure of \$61.05/mil gal. The same approach is taken for interest and support services. When these are added together, a total cost/mil gal for water to a given zone results. For example, the total cost of water delivered to Zone 3 is \$419.43/mil gal. Table 32 also contains the metered



Facility		Elevation (ft. above sea level)
KCW	Kansas City Waterworks	754
EB	East Bottoms	752
W	Waukomis	
TC	Turkey Creek	775
WB	Waldo Booster	1,008
BR	Blue Ridge	1,011

Figure 14. Kansas City Water Department facilities (arrows depict general direction of water flow).

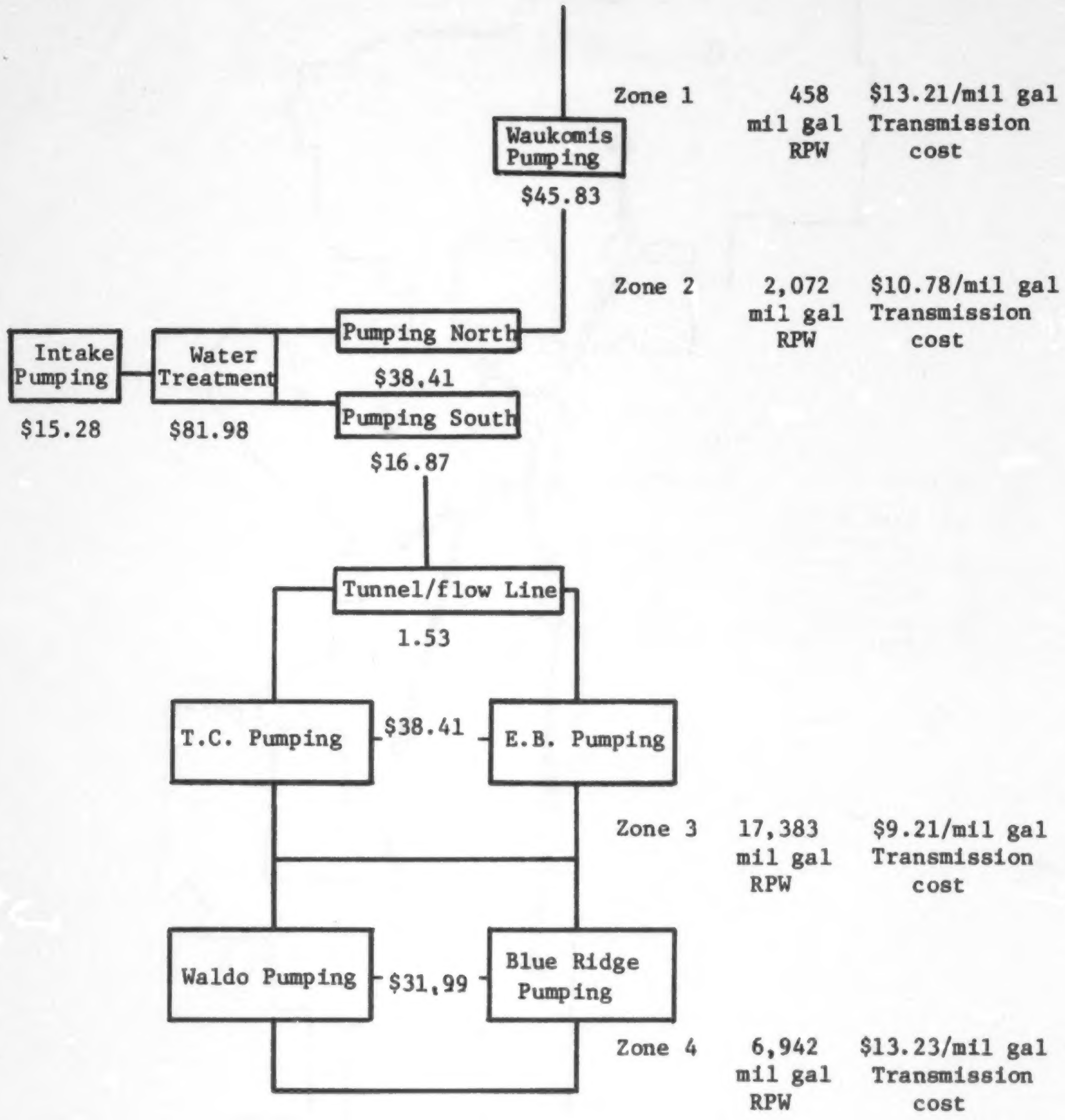

Zone 1
458 mil gal RPW
$13.21/mil gal Transmission cost
Waukomis Pumping
$45.83
Zone 2
2,072 mil gal RPW
$10.78/mil gal Transmission cost
Intake Pumping
$15.28
Water Treatment
$81.98
Pumping North
$38.41
Pumping South
$16.87
Tunnel/flow Line
1.53
T.C. Pumping
$38.41
E.B. Pumping
Zone 3
17,383 mil gal RPW
$9.21/mil gal Transmission cost
Waldo Pumping
$31.99
Blue Ridge Pumping
Zone 4
6,942 mil gal RPW
$13.23/mil gal Transmission cost

Figure 15. Kansas City Water Department allocation of capital and operating expenses to water system components ($/mil gal RPW).

TABLE 32. KANSAS CITY WATER DEPARTMENT COST, CONSUMPTION, AND REVENUE, BY ZONE

Zone	Incremental costs ($/mil gal)	Distribution costs ($/mil gal)	Interest ($/mil gal)	Support services ($/mil gal)	Total cost* ($/mil gal)	RPW (mil gal)	Revenue
1	$205.40	$61.05	$50.32	$144.52	$461.33	458	$ 211,289
2	146.36	61.05	50.32	144.52	402.25	2,072	833,462
3	163.19	61.05	50.32	144.52	419.43	17,383	7,290,952
4	208.45	61.05	50.32	144.52	464.34	6,942	3,223,448
Total	---	---	---	---	---	26,855	11,559,151

* Average cost/zone is $436.83

consumption for each of the pressure areas and the estimated contributions of revenue for recovering the total cost.

Once these calculations are made and various cost zones are established, costs versus charges can be examined. Tables 33, 34, and 35 contain the Kansas City rate schedules.

The cost of water for the 10 largest consumers of the Kansas City Water Department is broken down in Table 36.

The locations of these 10 major users within the service area are shown in Figure 16. By comparing each location with the cost allocations in Table 32, it is possible to identify the actual allocated cost of delivering water to the individual consumer. This comparison shows that in some cases the water department is recovering its cost for water, and in other cases, the charge is substantially less than the actual cost of producing and delivering the water.

Average costs for all RPW during the most recent year studied are as follows:

	$/mil gal
Support services	145
Acquisition	15
Treatment	82
Distribution	138
Interest	50
Total	430

TABLE 33. KANSAS CITY WATER DEPARTMENT METER RATES ($/mil gal)

Meter size (in.)	City rate	Suburban rate
5/8	$ 1.30	$ 2.20
3/4	1.50	2.50
1	1.85	3.30
1-½	2.50	4.50
2	3.75	6.50
3	7.50	12.50
4	12.50	22.00
6	25.00	44.00
8	37.50	66.00
10	55.00	93.00

TABLE 34. KANSAS CITY WATER DEPARTMENT COMMODITY CHARGES

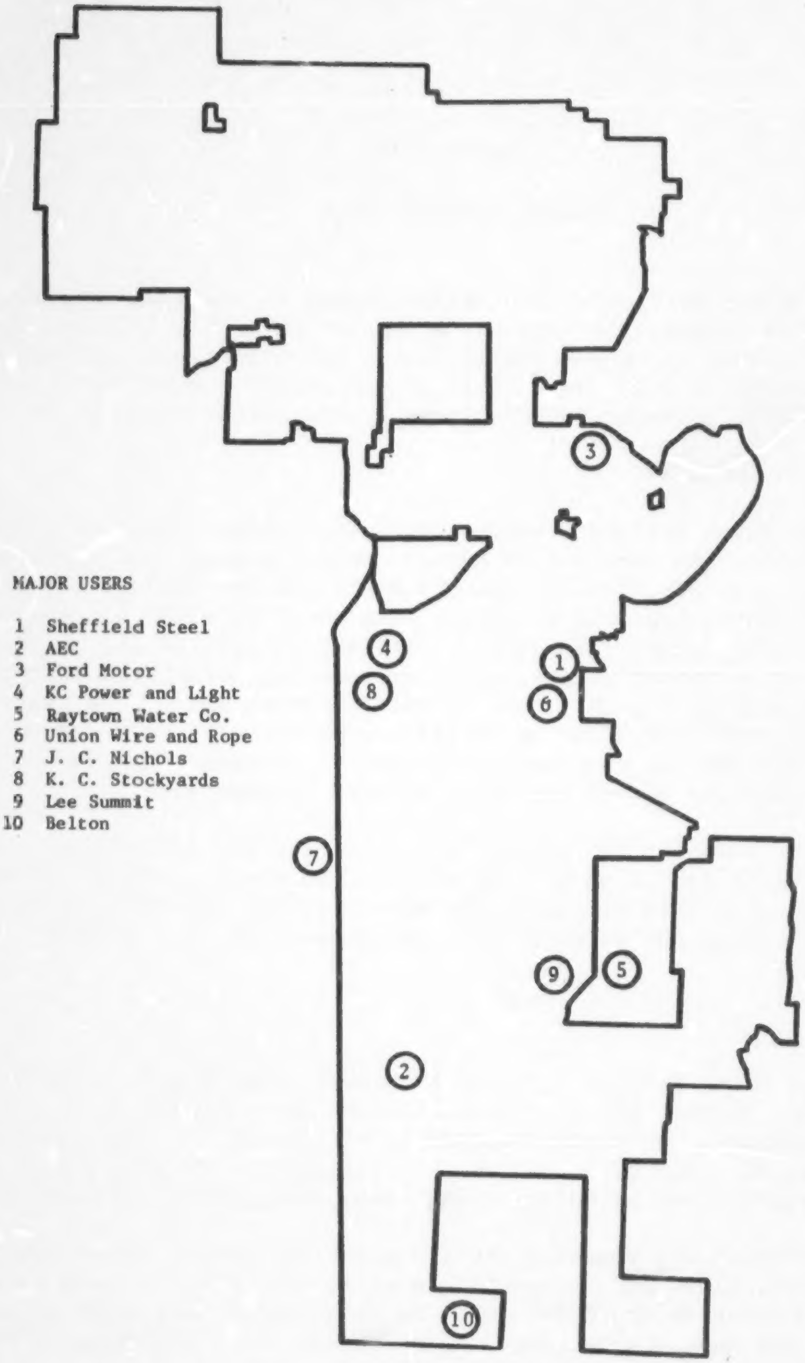
Item	Amount ($/mil gal)
City:	
First 50 units @ $.39	$521.35
Next 250 units @ $.28	374.31
Next 4,700 units @ $.23	307.47
Over 5,000 units @ $.14	187.15
Suburban:	
First 20 units @ $.53	708.50
Next 480 units @ $.44	588.19
Over 500 units @ $.32	427.78

TABLE 35. KANSAS CITY WATER DEPARTMENT CHARGE ANALYSIS

		Total charge	
Units served	Gallons used	City	Suburban
13.4	10,000	$5.22	$7.01
5,000	3,740,260	1,170.56	1,661.80
100,000	74,805,200	14,470.32	32,061.80
150,000	112,207,800	21,470.22	48,061.80

TABLE 36. KANSAS CITY WATER DEPARTMENT WATER COSTS FOR 10 MAJOR USERS

Major Users	High or low month	Month	Units used (mil gal)	Amount billed	Unit Charge ($/mil gal)	Location	Cost zone
Sheffield Steel	High	5	120.6	$23,055	$191.16	City	3
	Low	3	74.7	14,435	193.21		
AEC	High	6	112.6	21,804	193.68	City	4
	Low	10	16.8	3,670	218.73		
Ford Motor Co.	High	5	53.1	22,778	428.99	Suburb	2
	Low	11	14.3	6,164	432.35		
K. C. Power & Light	High	10	46.4	9,188	198.08	City	3
	Low	3	10.2	2,389	234.62		
Raytown Water Co.	High	6	41.9	17,960	428.94	Suburb	3
	Low	1	21.1	9,063	430.42		
Union Wire & Rope	High	5	24.5	5,077	206.84	City	3
	Low	6	5.5	1,462	266.89		
J. C. Nichols	High	12	31.5	13,532	429.95	Suburb	3
	Low	4	6.0	2,645	438.42		
K. C. Stockyards	High	10	16.9	2,488	147.03	Flowline	3
	Low	9	9.8	1,442	147.09		
Lee Summit	High	12	28.1	12,087	430.20	Suburb	4
	Low	9	4.0	1,759	443.50		
Belton	High	12	37.0	15,892	429.62	Suburb	4
	Low	9	5.4	2,355	437.80		



MAJOR USERS

1	Sheffield Steel
2	AEC
3	Ford Motor
4	KC Power and Light
5	Raytown Water Co.
6	Union Wire and Rope
7	J. C. Nichols
8	K. C. Stockyards
9	Lee Summit
10	Belton

Figure 16. Locations of 10 major users within the Kansas City service area.

SECTION 7

DALLAS WATER UTILITY

The City of Dallas lies within Dallas County in north central Texas. Based on the 1970 census, the city has a population of 942,462, and the population of the county is nearly 1.6 million. The Dallas metropolitan area is growing at the rate of 3.1%/year. This growth rate has many implications for urban services such as water supply. Some system facts are shown in Table 37.

WATER SUPPLY SERVICE AREA

The Dallas Water Utility provides water on a retail basis to all classes of customers within the city's five service areas (Figure 17). Treated water is supplied to 19 cities ("county towns") within Dallas County, and also to the Dallas-Fort Worth Regional Airport. Some water is also sold to communities outside Dallas County. Service is provided to each of the cities through one or more master meters, and contracts are negotiated individually by the utility with each county town or water service area. The contracts are for 1 to 50 years, with 20- or 30-year contracts being most common. The total consumption for the customer cities and the airport in 1974 was 12,438 mil gal, approximately 20% of the total metered consumption.

The rate of increase in the population is expected to continue. A great deal of emphasis is placed on meeting the treated water needs of the Dallas county towns as they turn to the Dallas Water Utility for additional water. At present, financing and developing of new reservoirs is a primary concern for the utility.

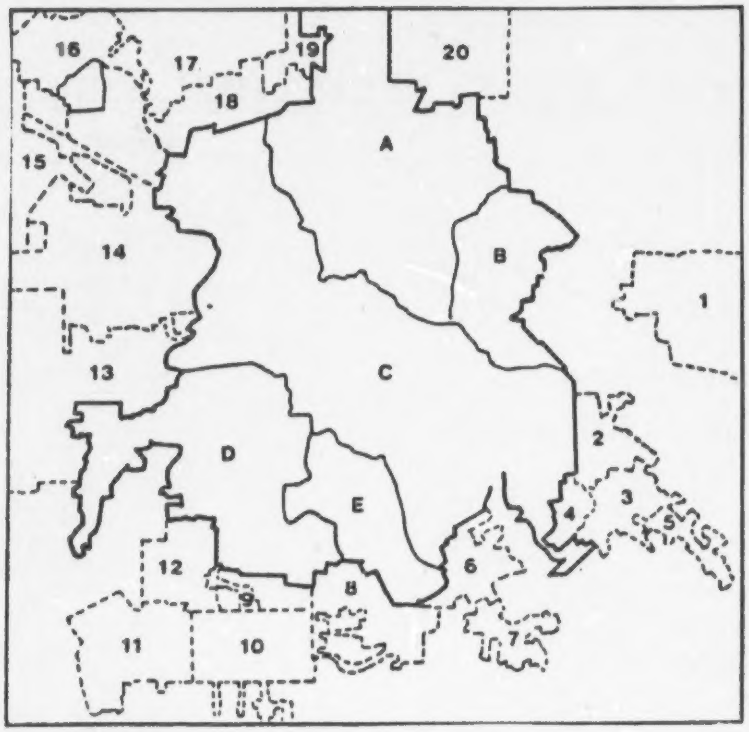
ORGANIZATION

The Dallas Water Utility combines both water supply and wastewater treatment functions. Because the accounting systems are also combined, it was necessary to estimate the costs assigned to each operation where overlap in functions occurred. The structure of the organization (Figure 18) is composed of engineering and planning, operations, and business sections.

The Engineering and Planning Section plans all system improvements, analyzes pumpage, flow, and consumption data to evaluate the adequacy of the system, and coordinates the development of long-range plans with engineering consultants. The Business Section is responsible for accounting, meter reading, billing, and collecting for the utility.

TABLE 37. DALLAS WATER UTILITY, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	2,729,356
County	1,549,221
Retail service area	942,462
Area of retail service area (sq miles)	301.38
Recognized customer classes (no. of meters)	
Residential	201,830
Commercial	20,508
Government	1,015
Apartment	5,272
Industrial	129
Suburban cities	35
Flat rate (no. accounts)	None
Percent metered	100
Purchased water (mil gal treated)	2,770
Source water	100% surface impoundment
Pipe in system (miles)	3,208
Elevation of treatment plants (ft above mean sea level):	
Bachman	446
Elm Fork	458
East Side	480 (146)
Elevation of service area (min-max ft)	430 - 875
Revenue-producing water (mil gal)	63,030
Treated water (pumpage from treatment plants + treated purchased water, mil gal)	70,656
Maximum day/maximum hour (MGD)	433/665



CUSTOMER CITIES
OUTSIDE DALLAS

1	Sunnyvale
2	Balch Springs
3	Kleberg
4	Rylie
5	Seagoville
6	Hutchins
7	Wilmer
8	Lancaster
9	Woodland Hills
10	DeSoto
11	Cedar Hill
12	Duncanville
13	Grand Prairie
14	Irving
15	Regional Airport
16	Coppell
17	Carrollton
18	Farmers Branch
19	Addison
20	Richardson

CITY OF DALLAS SERVICE AREAS

A	North High
B	East High
C	Central Low
D	South High
E	Trinity Heights - Cedardale Intermediate

Figure 17. Dallas Water Utility water supply service area.

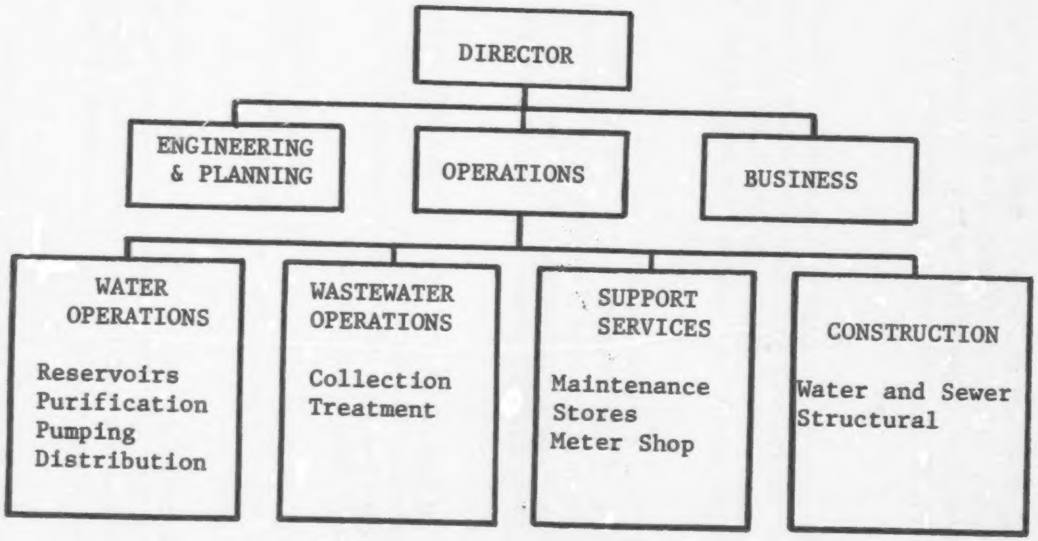

DIRECTOR
ENGINEERING & PLANNING
OPERATIONS
BUSINESS
WATER OPERATIONS
Reservoirs
Purification
Pumping
Distribution
WASTEWATER OPERATIONS
Collection
Treatment
SUPPORT SERVICES
Maintenance
Stores
Meter Shop
CONSTRUCTION
Water and Sewer
Structural

Figure 18. Dallas Water Utility organizational structure.

The Water Operations Division is the largest of the four divisions within the Operations Sections. All water production and distribution functions are handled by this division. The Wastewater Operations Division is responsible for the collection and treatment of wastewater. The Support Services Division maintains equipment and meters and is responsible for storage of spare parts. The Construction Division supervises the installation of additions to the system.

All three sections handle both wastewater and water supply responsibilities through the division level. The only division handling water supply is the Water Operations Division. Separate costs are maintained for both water and wastewater activities by the business section.

ACQUISITION

Raw water comes from five major reservoirs and is treated in treatment plants located in the northwest, central, and southeast sections of the city. The treatment plants are generally located in the low-lying areas, thus requiring that water be pumped up to residences and businesses located at higher elevations.

Dallas paid $5.5 million toward the cost of dams to be built at Lewisville on the Elm Fork of the Trinity River and at Grapevine on Denton Creek. The remaining construction cost for the dams was paid by the Federal government. In return the Federal government reserved 163 billion gallons of water in the Garza-Little Elm and Grapevine reservoirs exclusively for Dallas' use.

Lavon reservoir is operated by the North Texas Municipal Water District. Under the terms of a contract, Dallas will be provided until 1991 with an average of 10 MGD of treated water, which is furnished to the northeast section of the city at the Casa View station.

Lake Ray Hubbard on the East Fork of the Trinity River has a capacity of 181 billion gallons. It was built for water supply only and is owned entirely by Dallas.

Lake Tawakoni is located on the Sabine River and lies in an entirely different watershed from Dallas. The reservoir and dam were built by Dallas and the U.S. Corps of Engineers and turned over to the Sabine River Authority in return for 80% of the water yield. The lake normally holds 306 billion gallons.

Waters from the Garza-Little Elm and Grapevine reservoirs flow in natural channels to points near the Bachman and Elm Fork treatment plants. At these plants, the raw water is removed from the channel by pumps located in the treatment facility.

Water from Lake Hubbard is pumped directly to the East Side treatment plant by a remote pump station controlled by the treatment plant.

Water from Lake Tawakoni is pumped 18 miles through a 60-in. pipeline to a 266-mil gal interim reservoir located on the ridge separating the Sabine and East Fork watersheds. The water then flows by gravity to the East Side treatment plant.

TREATMENT

Raw water is treated at Elm Fork, Bachman, and East Side. Each facility was constructed at a different time in response to increasing demands.

The Elm Fork treatment plant, completed in 1952, is about 4 miles northwest of the city and has a capacity of 196 MGD. It is equipped with activated carbon facilities in addition to chlorinators, primary and secondary flocculators, and settling tanks. It also houses a 13.2-mil gal clear well storage facility. Onsite pumping facilities include five 30-MGD at 58 feet of head, low-service pumps, four 30-MGD and one 15-MGD at 280 feet discharge head, high-service pumps, plus additional wash-water pumps. The high-service pumps put water directly into the distribution system.

The Bachman purification plant, located within the city limits, was completed in 1930 and has a capacity of 116 MGD. Its design is similar to that of Elm Fork, but it has no secondary flocculators. The plant has four centrifugal water pumps, 14 high-service pumps, and one wash-water pump. The clear wells at Bachman have a total capacity of 20 mil gal, and the high-service pumps put water directly into the distribution system.

The East Side treatment plant, about 5 miles east of the city, was completed in 1964. Its design capacity is 205 MGD, and it has flocculators, primary clarifiers, secondary settling basins, and filters. There are no low-service pumps located at the plant because water flows from the interim reservoir by gravity.

In the chemical treatment processes, seven chemicals are fed into the plants in proportion to the amount of water treated, but the quality of the raw water determines the specific amount of each chemical used. The chemicals used, their purpose, and the order of application are as follows:

1. Activated carbon is used to absorb organic matter and to control taste and odor.

2. Chlorine is added in the initial phases of treatment to start the process of killing bacteria, to prevent the growth of algae in the basins, and to oxidize organic matter.

3. Lime serves as a softening agent, combines with other chemicals to settle out suspended matter, and adjusts the alkalinity of the water to make it less corrosive.

4. Ferric sulfate is the chief clarifying agent. It combines with part of the lime.

5. Fluosilicic acid is the flouridating agent and is added at the end of the first settling stage. If needed, more ferric sulfate is added at this point.

6. Sodium hexametaphosphate is added for scale and corrosion control.

7. Ammonia is added as a disinfectant along with chlorine; it also makes the taste of the chlorine less noticeable.

8. Chlorine is added again.

Of the chemicals used, all of the carbon and ferric sulfate and nearly all of the lime settle out in the plant as sludge. Most of the pre-chlorine is consumed, a trace of the lime and the ammonia, post-chlorine, fluoride, and hexametaphosphate remain in the water going to the consumer. Figure 19 shows the plan and functions of a Dallas treatment plant.

TRANSMISSION AND DISTRIBUTION

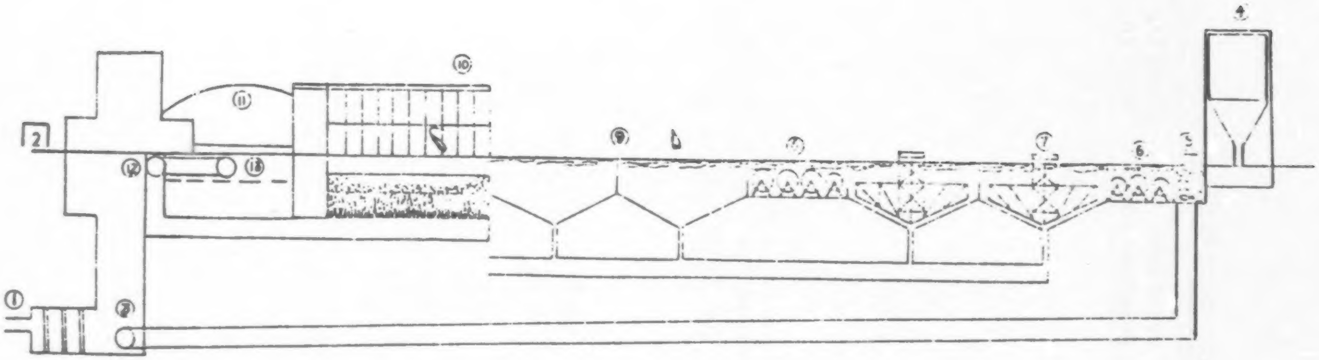
The distribution system consists of approximately 3,208 miles of mains composed of 2- to 90-in. pipe. To direct the flow of water to the proper areas and to control pressure, 32,000 valves have been installed. There are eight elevated tanks in the system to provide pressure together with 10.5 mil gal storage for peak demand periods. A difference of about 360 ft in elevation exists between the areas along the river channel and the surrounding hills.

The line from the East Side treatment plant to the Lake June reservoir is concrete pipe 90 in. in diameter. Transmission to the Southcliff reservoir is through a small line.

The Elm Fork plant pumps into a line to serve the city; it also serves the City of Irving through a 40-in. pipe, and Grand Prairie through a 36-in. line beyond Irving.

The Bachman plant pumps into three 36-in. lines that fan out over the central part of the city into the business district and on to South Dallas.

Within the distribution system, nine ground storage reservoirs have a total capacity of 141.87 mil gal. Each reservoir is paired with a high-pressure pump station to boost water into the distribution system under enough pressure to deliver it to the customer. The eight elevated storage tanks provide: 1) slack in the system so that the pumps are not pumping against a closed system and overheating, 2) an additional 10.5 mil gal storage. During peak consumption when it is impossible for booster pumps to deliver enough water to remote areas within the system, water is provided to these areas by gravity from the elevated tanks. Table 38 lists system storage facilities.



(1) Raw water conduits.

(2) Carbon storage for control of taste and odor.

(3) Raw water pumps - pump water to chemical building. Gravity flow from chemical building through plant to clear wells.

(4) Chemical building - where chlorine, lime, alum and ferric sulfate are added for purification and softening.

(5) Rapid mixers - chemicals and river water are mixed.

(6) Primary flocculators - chemicals are slowly mixed until chemical reactions take place.

(7) Primary settling tanks - chemicals and suspended matter settle out.

(8) Secondary flash mixers and flocculators - more chemicals may be added to increase clarification in final settling tanks, or control taste and odor.

(9) Secondary settling basin - final settling of treated water to remove most of the suspended solids.

(10) Filters - filtration through sand for removal of remaining suspended matter that will not settle. A small quantity of chlorine and ammonia is added after filtration to assure removal of all bacteria.

(11) Clear wells - to store treated purified water at the plant until needed.

(12) Filtered water pumps - to pump the treated water to distribution system.

(13) Supply main to Dallas.

Figure 19. Plan of a Dallas water treatment plant.

TABLE 38. DALLAS WATER UTILITY STORAGE FACILITIES

Type of storage	Ground elevation (ft)	Overflow elevation (ft)	Capacity* (mil gal)
Elevated storage tanks:			
Cedardale	586	702	0.5
Forest Lane	632	752	2
Garland Road	603	714	2
Plano Road	617	752	2
Red Bird	746	875	1
Trinity Heights	612	717	1
Western Hills	685	787	1
Western Hills (ground storage)	686	767	1
	Elevation bottom (ft)	Elevation top (ft)	Capacity (mil gal)
Ground storage reservoirs:			
Beltwood	623	643	10.0
Casa View	547	562	3.5
Greenville	608	627	21.6
Lake June	494	516	21.4
Southcliff	584	606	26.0
Sunset	608	627	15.9
Walcrest	626	648	20.1
Bachman+	429+	444	10.0
Elm Fork+	443+	459	13.3

* Total storage capacity is 152.3 mil gal.

+ Clear well

COST ANALYSIS

Growth in consumer demand for water from 1964 through 1974 is shown in Figure 20.

Using the standard cost categories defined earlier, data were collected and reported as shown in Tables 39, 40, and 41. As indicated by the relative increases in the support services category, a major portion of the operating budget was expended for labor. Table 42 examines the labor costs associated with operations and maintenance and gives the total payroll expended along with the total number of man-hours on payroll.

Table 42 shows that the cost/man-hour has increased over 10 years by 131%, whereas the total payroll hours required to produce 1 mil gal of RPW decreased by 22%. Thus the operating cost for producing water did not increase as rapidly as the labor cost/man-hour. When it is no longer possible to gain increasing efficiencies with respect to manpower, the payroll cost will start to increase at the same rate as the labor cost.

Table 43 summarizes operating and capital costs for the 10-year period of analysis and Table 44 lists capital and operating expense ratios. The operating expenses are costs incurred in normal day-to-day operations. Capital expenses are the total of the depreciated values of the periodic expenditures on major equipment items and facilities plus the interest charged on money borrowed for that purpose.

A comparison of the operating and capital expenses as a percent of the total cost shows that more expenses were associated with operations than with capital. Over the 10-year period, this trend continued primarily because of a continued increase in the cost of items associated with operations, such as salaries. Capital costs also increased slightly, but not at the same rate as operating expenses.

Because the Dallas system is relatively old, the capital depreciated was expended when costs were significantly lower. On the other hand, the operating expense is in current dollars. This ratio will change whenever capital investments are made by the utility. For example, major expenditures are planned for constructing new reservoirs and pipelines. When this occurs, the ratio of capital to operating expense will increase significantly.

SYSTEM COSTS

Examination of the costs on a functional basis is only part of the total cost picture. Since the purpose of a water supply utility is to deliver water to a consumer, it is important to be able to present costs in such a way that they relate to the delivery of water to a demand point within the utility's distribution [illegible]. The functional categories, both operating and capital, will therefore be reaggregated and assigned to physical components in the water delivery system.

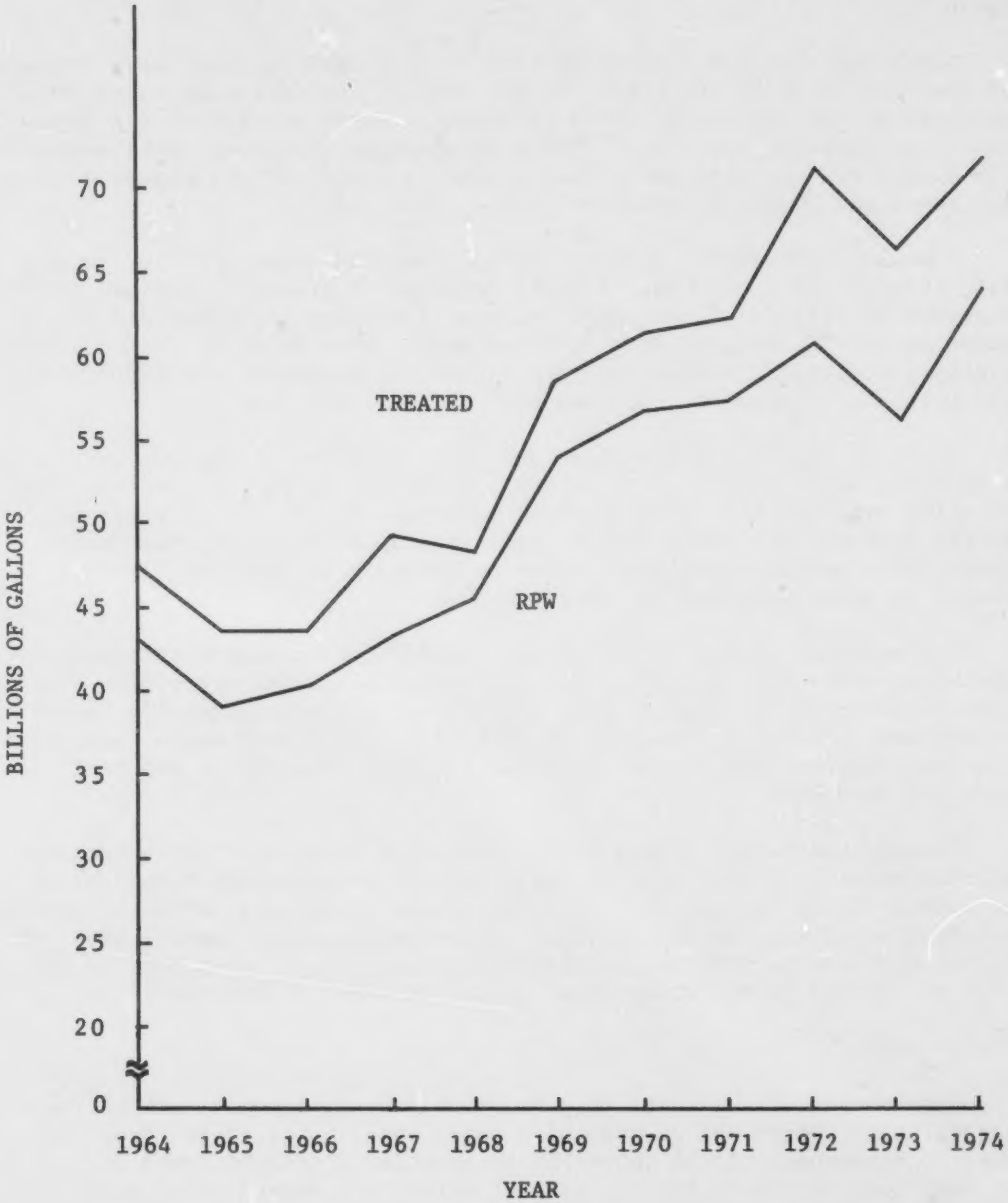


Figure 20. Dallas Water Utility water flow: treated water versus RPW.

TABLE 39. DALLAS WATER UTILITY ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$ 530,135	$ 540,798	$ 616,410	$ 707,941	$ 957,709	$1,189,749	$1,320,763	$ 537,166	$ 677,837	$ 509,168
Acctg & collection	822,425	907,782	1,043,523	1,161,223	1,322,772	1,474,440	1,552,938	1,716,325	2,099,736	1,928,061
Other	2,610	2,329	4,054	3,675	4,811	5,993	618,498	1,510,872	1,624,958	2,263,210
Total overhead	1,355,170	1,450,909	1,663,987	1,872,839	2,285,292	2,670,182	3,492,199	3,764,363	4,402,531	4,700,439
Acquisition:	524,440	537,779	597,257	515,147	495,129	501,031	577,571	533,481	756,126	688,105
Treatment:										
Supervision and labor	556,380	577,366	573,028	655,615	766,745	879,388	1,032,354	1,079,892	1,166,396	1,240,568
Chemicals and supplies	693,419	706,144	729,556	723,275	838,152	836,382	888,443	907,206	1,009,252	1,151,276
Other	127,316	165,173	145,665	130,784	154,199	185,992	285,408	319,931	397,390	396,605
Total treatment	1,377,115	1,448,683	1,448,249	1,509,674	1,759,096	1,901,762	2,206,205	2,307,029	2,573,038	2,788,449
Power and pumping:										
Supervision and labor	454,234	454,181	515,622	562,015	636,310	676,597	802,553	933,639	928,523	849,759
Miscellaneous services	489,789	502,600	530,983	528,055	655,995	673,864	642,147	766,508	876,909	892,073
Other	55,148	45,978	47,600	52,817	43,349	53,842	76,134	81,006	102,275	64,421
Total power and pumping	999,171	1,002,759	1,094,205	1,142,887	1,335,654	1,404,303	1,520,834	1,781,153	1,907,707	1,806,253
Transmission and distribution:										
Supervision and labor	894,528	975,233	1,095,557	1,242,960	1,352,503	1,466,236	1,368,530	1,608,508	1,787,916	1,952,521
Maintenance	261,572	291,502	299,637	284,162	259,426	316,959	351,940	413,654	411,147	406,501
Miscellaneous services	188,285	212,094	210,432	214,990	253,241	266,819	276,539	325,031	431,043	54,309
Other	86,392	93,499	86,752	104,634	97,390	128,756	107,110	125,893	120,684	131,464
Total trans. & dist.	1,430,777	1,572,328	1,692,378	1,846,746	1,962,560	2,178,770	2,104,119	2,473,086	2,750,790	2,544,794
Total operating cost	5,686,673	6,012,458	6,496,076	6,887,293	7,837,731	8,656,048	9,900,928	10,859,112	12,390,192	12,528,040

TABLE 40. DALLAS WATER UTILITY UNIT OPERATING COSTS ($/MIL GAL RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$ 13.50	$ 13.72	$ 14.29	$ 15.60	$ 17.92	$ 21.07	$ 23.35	$ 8.85	$ 12.11	$ 8.08
Accounting and collection	20.94	23.04	24.19	25.59	24.75	26.11	27.46	28.28	37.50	30.59
Other	0.07	0.06	0.09	0.08	0.09	0.11	10.94	24.89	29.02	35.91
Total overhead	34.51	36.82	38.57	41.27	42.76	47.29	61.75	62.02	78.63	74.57
Acquisition:	13.35	13.65	13.85	11.35	9.26	8.87	10.21	8.79	13.50	10.92
Treatment:										
Supervision and labor	14.17	14.65	13.28	14.45	14.34	15.57	18.25	17.79	20.83	19.68
Chemicals and supplies	17.66	17.92	16.91	15.94	15.68	14.81	15.71	14.95	18.01	18.27
Other	3.24	4.19	3.38	2.88	2.88	3.29	5.05	5.27	7.10	6.29
Total treatment	35.07	36.76	33.57	33.27	32.90	33.67	39.01	38.01	45.95	44.24
Power and pumping:										
Supervision and labor	11.57	11.53	11.95	12.39	11.90	11.98	14.19	15.38	16.58	13.48
Power	12.47	12.76	12.31	11.64	12.27	11.93	11.35	12.63	15.66	14.15
Other	1.40	1.17	1.10	1.16	0.81	0.95	1.35	1.33	1.83	1.02
Total power and pumping	25.44	25.46	25.36	25.19	24.98	24.86	26.89	29.34	34.07	28.66
Transmission and distribution:										
Supervision and labor	22.78	24.75	25.40	27.39	25.30	25.96	24.20	26.50	31.93	30.98
Maintenance	6.66	7.40	6.95	6.26	4.85	5.61	6.22	6.81	7.34	6.45
Miscellaneous services	4.79	5.38	4.88	4.74	4.74	4.72	4.89	5.35	7.70	0.86
Other	2.20	2.37	2.01	2.31	1.82	2.28	1.89	2.07	2.16	2.09
Total transmission and distribution	36.43	39.90	39.24	40.70	36.71	38.57	37.20	40.73	49.13	40.37
Total operating cost	144.80	152.59	150.29	151.78	146.61	153.26	175.06	178.89	221.28	198.76

TABLE 41. DALLAS WATER UTILITY OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	9.32	8.99	9.49	10.28	12.22	13.75	13.34	4.95	5.47	4.07
Accounting and collection	14.46	15.10	16.06	16.86	16.88	17.04	15.69	15.81	16.95	15.39
Other	.05	.04	.06	.05	.06	.07	6.25	13.91	13.11	18.08
Total support services	23.83	24.13	25.61	27.19	29.16	30.86	35.28	34.67	35.33	37.54
Acquisition:	9.22	8.95	9.20	7.48	6.32	5.79	5.83	4.91	6.10	5.49
Treatment:										
Supervision and labor	9.79	9.60	8.82	9.52	9.78	10.16	10.42	9.94	9.41	9.90
Chemicals and supplies	12.20	11.74	11.23	10.50	10.70	9.66	8.97	8.36	8.14	9.19
Other	2.24	2.75	2.24	1.90	1.96	2.15	2.88	2.94	3.21	3.16
Total treatment	24.23	24.09	22.29	21.92	22.44	21.97	22.27	21.24	20.76	22.25
Power and pumping:										
Supervision	7.99	7.56	7.94	8.16	8.12	7.82	8.11	8.60	7.49	6.78
Power	8.61	8.36	8.17	7.67	8.37	7.78	6.48	7.06	7.08	7.12
Other	0.97	0.77	0.73	0.76	0.55	0.62	0.77	0.74	0.83	0.51
Total power and pumping	17.57	16.69	16.84	16.59	17.04	16.22	15.36	16.40	15.40	14.41
Transmission and distribution:										
Supervision and labor	15.73	16.22	16.87	18.05	17.26	16.94	13.82	14.81	14.43	15.59
Maintenance	4.60	4.85	4.61	4.12	3.31	3.66	3.55	3.81	3.32	3.25
Miscellaneous services	3.31	3.53	3.24	3.12	3.23	3.08	2.79	2.99	3.48	0.43
Other	1.52	1.55	1.33	1.52	1.24	1.49	1.08	1.16	0.97	1.05
Total transmission and distribution	25.16	26.15	26.05	26.81	25.04	25.17	21.24	22.77	22.20	20.32

TABLE 42. DALLAS WATER UTILITY LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)*	2,039,838	2,187,844	3,126,940	3,468,600	3,936,236	4,398,157	5,148,817	5,688,610	6,102,292	6,296,936
Total hours on payroll	1,753,440	1,759,680	1,724,320	1,768,000	1,734,720	1,828,320	2,028,000	2,186,080	2,302,560	2,204,800
RPW (mil gal)	39,274	39,404	43,135	45,372	53,451	56,472	56,555	60,698	55,994	63,030
Total payroll/mil gal	51.94	71.51	72.49	76.45	73.64	77.88	91.04	93.39	108.98	99.90
Total hours/mil gal	44.65	44.66	39.97	38.97	32.45	32.38	35.86	38.02	41.12	34.98
Average cost/man-hour+	1.16	1.24	1.81	1.96	2.27	2.41	2.54	2.60	2.65	2.86

* Includes operations and maintenance payroll only.

+ Includes all water utility man-hours.

TABLE 43. DALLAS WATER UTILITY OPERATING AND CAPITAL COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense	$ 5,686,674	$ 6,012,457	$ 6,496,075	$ 6,887,291	$ 7,837,731	$ 8,656,048	$ 9,900,927	$10,859,112	$12,390,193	$12,528,040
Depreciation	2,978,901	3,175,888	3,339,206	3,494,015	3,687,875	3,814,911	3,985,751	4,406,954	4,751,860	5,135,253
Interest	1,917,672	1,951,243	2,088,277	2,245,807	2,196,370	2,804,185	2,192,802	2,508,647	3,424,568	3,637,576
Total	10,583,253	11,139,588	11,923,558	12,627,113	13,721,976	14,555,144	16,079,480	17,774,713	20,566,621	21,300,869
Total unit cost/mil gal RPW	269.46	282.70	276.42	278.30	256.72	257.74	284.31	292.83	367.29	337.94

TABLE 44. DALLAS WATER UTILITY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating cost ($)	5,686,674	6,012,457	6,496,075	6,887,291	7,837,731	8,656,048	9,900,927	10,859,112	12,390,193	12,528,040
Capital cost ($)	4,396,573	5,127,131	5,427,483	5,739,822	5,884,245	5,899,096	6,178,553	6,915,601	8,176,428	8,772,829
Total ($)	10,583,253	11,139,568	11,923,558	12,627,113	13,721,976	14,555,144	16,079,480	17,774,713	20,566,621	21,300,869
Operating cost as % of total	53.73	53.97	54.48	54.54	57.11	59.47	61.57	61.09	60.24	58.81
Capital cost as % of total	46.27	46.03	45.52	46.46	42.89	40.53	38.43	38.91	39.76	41.19
Capital labor cost ratios	2.16	2.34	1.74	1.65	1.49	1.34	1.20	1.22	1.34	1.39

Locations of treatment plants and pump stations in the Dallas service area are shown in Figure 21. The Elm Fork and Bachman treatment plants contain seldom used, high-pressure pumps for moving water to the Lake June pump station, where all the water treated at East Side is pumped into the distribution system.

To analyze the impact of the cost of water as it moves from acquisition to treatment to the consumer, it is necessary to identify the capital and operating cost of each system component. Figure 22 is a schematic diagram of Figure 21 and shows the operating and capital cost for each of the system's major facilities. A linear assumption is made to demonstrate the accrual of costs/mil gal as water moves from one component of the system to another. For example, the acquisition cost of water going to the East Side treatment plant (Figure 21) is $54.62/mil gal, the cost of treatment is $78.08/mil gal, and the cost of pumping to Zone A is $20.34/mil gal. This results in a cost of $153.04/mil gal for water delivered to Zone A. As water passes through this zone, a transmission cost of $41.01/mil gal is added.

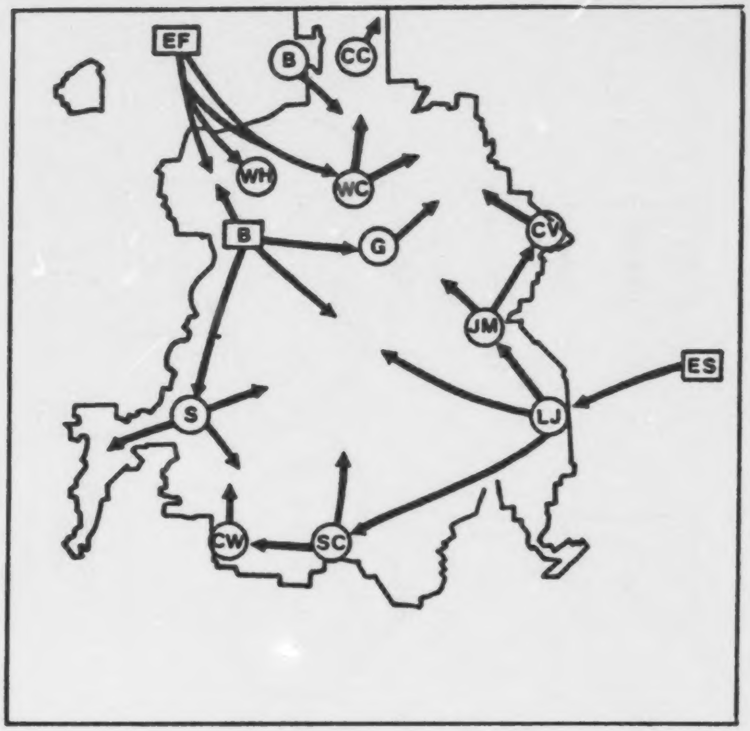
The schematic diagram shows the major water pathways as designated by 1, 2, or 3. The various cost zones are shown in column 1 of Table 45. According to the designation, for Zone 3A, the incremental cost is $153.04. These incremental costs include distribution, interest, support services.

Calculation of the distribution cost is based on the assumption that these are constant throughout the system. Therefore, the total capital and operating cost for distribution is divided by the number of gallons of RPW in 1973, yielding the figure $67.33/mil gal. The same approach is taken to calculate the interest and support services cost. When these costs are added, a total cost/mil gal for water delivered to a given zone results. For example, the total cost of water delivered in Zone 3A is $361.55/mil gal. Columns 7 and 8 of the Table 45 contain the metered consumption for each zone and the estimated revenue.

Once these calculations are made and various cost zones established, costs versus charges for a given set of consumers can be examined. Table 46 summarizes rates charged by the City of Dallas for typical monthly water consumption.

Water costs for the 10 largest consumers served by the Dallas Utility are shown in Table 47. For utility bills including both water and sewer service charges, it was necessary to calculate the portion of the bill allocated directly to water.

By converting units used to mil gal and dividing the monthly water service charge by this amount, it is possible to determine the unit cost ($/mil gal) paid by the consumer (Table 47). The actual allocated cost of delivering water to a specific consumer can be determined by comparing the location of each user with Table 45.



□ Treatment Plants		Elevation (ft above sea level)
EF	Elm Fork	458
B	Bachman	456
ES	East Side	480

○ Pump Stations		Elevation (ft above sea level)
B	Beltwood	622
CW	Camp Wisdom	693
CC	Cosa Crest	620
G	Greenville	609
JM	Jim Miller	521
LJ	Lake June	504
SC	Southcliff	586
S	Sunset	607
WC	Walcrest	627
CV	Casa View	562
WH	Walnut Hill	---

Figure 21. Dallas Water Utility treatment plants and pump stations (arrows depicit general direction of water flow).

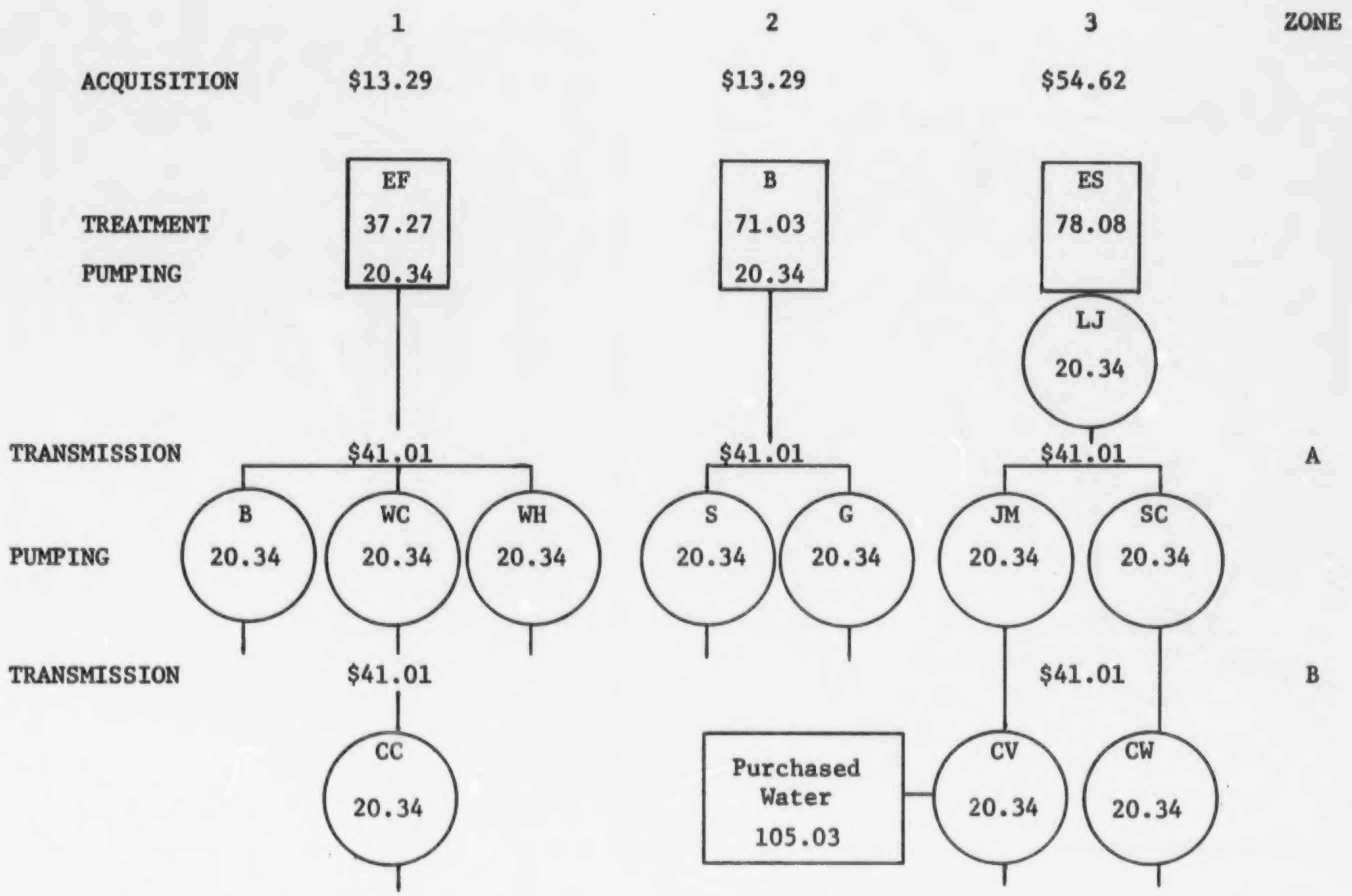

1
2
3
ZONE
ACQUISITION
$13.29
$13.29
$54.62
TREATMENT
PUMPING
EF
37.27
20.34
B
71.03
20.34
ES
78.08
LJ
20.34
TRANSMISSION
$41.01
$41.01
$41.01
A
PUMPING
B
20.34
WC
20.34
WH
20.34
S
20.34
G
20.34
JM
20.34
SC
20.34
TRANSMISSION
$41.01
$41.01
B
CC
20.34
Purchased
Water
105.03
CV
20.34
CW
20.34

Figure 22. Dallas Water Utility allocation of capital and operating expenses to water system components ($/mil gal RPW).

TABLE 45. DALLAS WATER UTILITY COSTS, CONSUMPTION, AND REVENUE, BY ZONE

Zone	Incremental costs ($/mil gal)	Distribution costs ($/mil gal)	Interest ($/mil gal)	General services ($/mil gal)	Total cost* ($/mil gal	RPW (mil gal)	Revenue
1 A	$70.90	$67.33	$57.72	$83.46	$279.41	16,766	$4,684,588.06
B	132.25	67.33	57.72	83.46	340.76	16,323	5,562,225.48
C	193.60	67.33					
C	193.60	67.33	57.72	83.46	402.11	223	89,670.53
2 A	104.66	67.33	57.72	83.46	313.17	7,872	2,465,274.24
B	166.01	67.33	57.72	83.46	374.52	6,854	2,566,960.08
3 A	153.04	67.33	57.72	83.46	361.55	4,212	1,522,848.60
B	214.39	67.33	57.72	83.46	422.90	6,936	2,933,234.40
C	275.74	67.33	57.72	83.46	484.25	1,287	623,299.75
CP	125.37	67.33	57.72	83.46	333.88	2,557	853,731.16
Total	---	---	---	---	---	63,030	21,301,762.30

* Average cost/zone is $337.96/mil gal.

TABLE 46. TYPICAL MONTHLY RATES FOR THE DALLAS WATER UTILITY

Class*	Meter size (in.)	Gallons consumed	Amount billed	Unit cost ($/mil gal)
Residential	5/8	10,000	$6.12	$612.00
Commercial	4	1,000,000	509.54	509.54
Industrial	---	25,000,000	5,316.00	212.64

* Multiply rates by 1.5 outside city limits.

TABLE 47. DALLAS WATER UTILITY COSTS FOR 10 MAJOR USERS

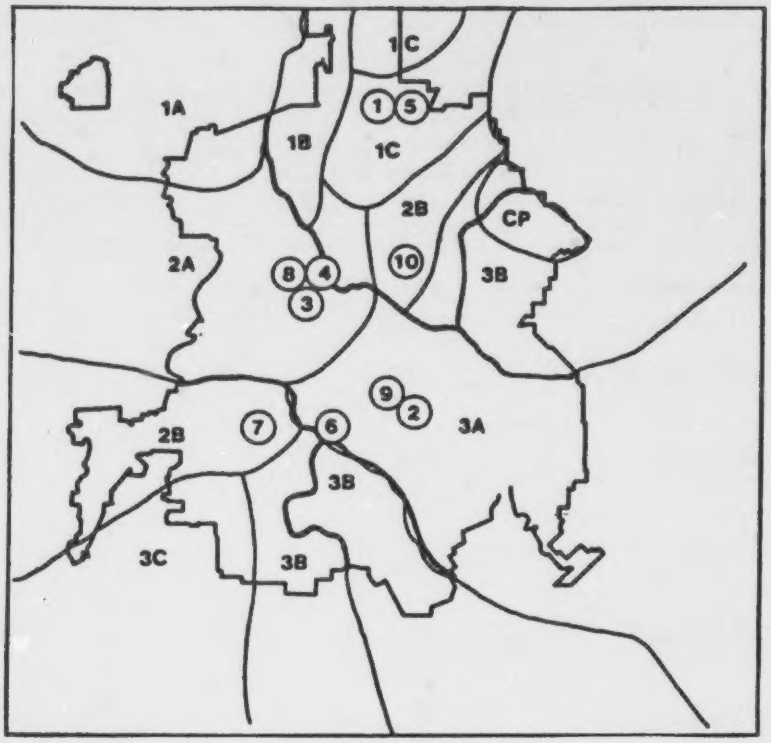
Major users	High or low month	Month	Units used (mil gal)	Amount allocated to water*	Unit charge ($/mil gal)	Cost zone
Texas Instruments	High	9	103.5	$18,487.62	$178.56	1B
	Low	1	78.0	13,932.94	178.44	
Procter and Gamble	High	9	27.5	7,717.08	280.54	3A
	Low	10	19.0	5,385.77	284.09	
Standard Brands	High	8	20.5	3,627.54	177.30	2A
	Low	4	14.3	3,675.77	257.05	
Texas Instruments	High	8	21.3	6,036.12	282.80	2A
	Low	2	9.3	2,763.96	295.80	
Texas Instruments	High	11	12.3	2,177.15	177.00	1B
	Low	1	7.5	1,304.57	173.94	
Clevepak Corp.	High	9	---	---	---	3A
	Low	11	13.8	1,984.13	143.77	
Stokely Van Camp	High	8	10.0	2,435.82	243.82	2B
	Low	11	10.0	1,755.25	175.70	
Morton Foods	High	9	7.5	3,150.98	422.38	2A
	Low	1	3.6	603.12	169.89	
Diamond Shamrock	High	7	5.2	1,624.82	314.52	3A
	Low	10	2.7	1,021.39	373.88	
Dr. Pepper Co.	High	9	8.1	1,425.00	174.91	2B
	Low	3	5.5	1,390.57	254.68	

* Denotes portion of combined water and sewer bill allocated directly to water.

Locations of the major users by cost zone are shown in Figure 23. The majority of these consumers are located along the central low area of the distribution system and are served directly from the treatment facilities. Some users, such as two of the Texas Instruments plants (1 and 3 on Figure 23), are located a considerable distance from the treatment plants and require significant transportation of water. Table 48 shows the costs associated with water delivery by cost zone and the amount actually paid by the consumer.

The average unit costs for all water supplied during the most recent year studied are as follows:

	$/mil gal
Support services-------	83
Acquisition------------	25
Treatment--------------	52
Distribution-----------	120
Interest---------------	58
Total------------------	338


1C
1A
①⑤
1B
1C
2B
CP
2A
⑧④
③
⑩
3B
⑨
②
3A
2B
⑦
⑥
3B
3C
3B

Identification Number	Major Users	Supply Area
1	Texas Instruments	1B
2	Procter and Gamble	3A
3	Standard Brands	2A
4	Texas Instruments	2A
5	Texas Instruments	1B
6	Clevepak Corporation	3A
7	Stokely Van Camp	2B
8	Morton Foods	2A
9	Diamond Shamrock	3A
10	Dr. Pepper Co.	2B

Figure 23. Dallas Water Utility cost zones and location of major users.

TABLE 48. DALLAS WATER UTILITY'S COSTS AND REVENUES FOR MAJOR USERS

Major users	Amount paid for high and low use month (1973) ($/mil gal)	Estimated delivery cost ($/mil gal)
Texas Instruments	$178.56 178.44	$340.76
Procter and Gamble	280.54 284.09	361.55
Standard Brands	177.30 257.05	313.17
Texas Instruments	282.80 295.80	313.17
Texas Instruments	291.45 43.69	340.76
Clevepak Corporation	--- 143.77	361.55
Stokely Van Camp	243.82 175.70	374.52
Morton Foods	422.38 169.89	313.17
Diamond Shamrock	314.52 373.88	361.55
Dr. Pepper Co.	174.91 254.68	374.52

SECTION 8

SAN DIEGO WATER UTILITY

The City of San Diego is located in San Diego County, which makes up the San Diego SMSA. The retail service area is made up of the City of San Diego (except for the South Bay area) and a small number of retail customers in San Diego County. The San Diego County Water Authority purchases raw water from the Metropolitan Water District of Southern California at a price that covers the operating costs of the County Water Authority and the Metropolitan Water District. The San Diego Water Utility makes in-lieu-of-tax payments to the Metropolitan Water District and the San Diego County Authority to cover the capital cost of the aqueducts. System facts are included in Table 49.

SERVICE AREA

The San Diego Water Utility provides water service on a retail basis to all classes of customers within the San Diego city limits. Treated water is also supplied to the California-American Water Company, the City of Del Mar, and miscellaneous users outside the city. The California-American Water Company in turn supplies retail customers within the South Bay area of the city.

In 1974, the San Diego Water utility sold 3025.6 mil gal to the California-American Water Company, 306.8 mil gal to Del Mar, and 64.2 mil gal to miscellaneous users outside the city; in addition, 49,039.8 mil gal were delivered to the City of San Diego. The service area is shown in Figure 24.

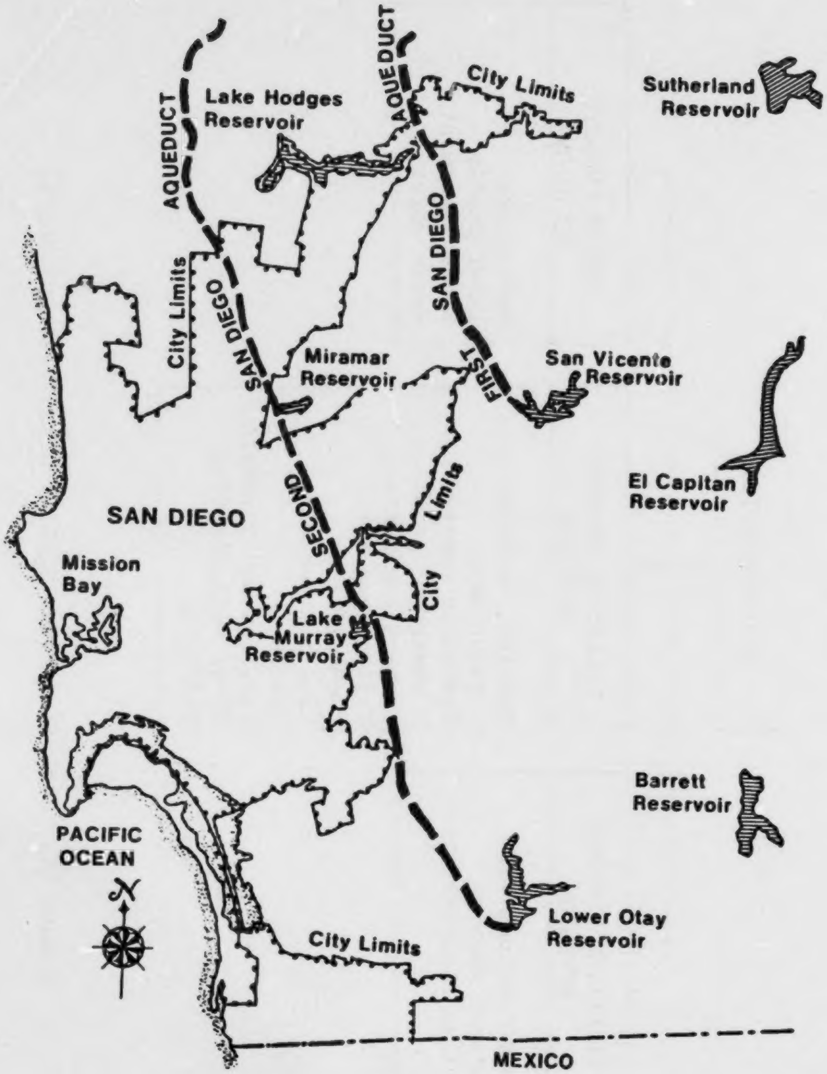
ORGANIZATION

The organizational structure of the San Diego Water Utility is illustrated in Figure 25. Included in the Service Division's functions are design engineering, customer service, and administrative support. The Systems Division is responsible for installation and maintenance of hydrants, manholes, valves, and mains. It is also responsible for hydraulic control, emergency services, systems engineering, utility plant checking, maps and records, meters, services and laterals, sewer main cleaning, and hydrology. The Water Quality Division is responsible for water supply, water treatment, wastewater collection and treatment, and the operation of the laboratory.

The water and wastewater functions of the San Diego Water Utility are combined at the division level, although separate accounts are maintained

TABLE 49. SAN DIEGO WATER UTILITY, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	1,562,100
County	1,562,100
Retail service area	761,916
Area of retail service area (sq miles)	Not available
Recognized customer classes:	
Single family domestic	139,378
Other domestic	24,953
Commercial	6,325
Industrial	234
Combined irrigation and domestic	42
Outside city services	60
Other utilities	5
Fire service	913
Flat rate (no. accounts)	135
Percent metered	100
Purchased water (raw, acre ft)	125,019.8
Source water	100% surface impoundments
Pipe in system (miles)	1,968
Elevation of treatment plants (ft above mean sea level):	
Alvarado	536
Otay	521
Miramar	715
Elevation of service area (min-max ft)	10/1020
Revenue-producing water (mil gal)	47,205
Treated water (flow from treatment plants, mil gal)	52,436
Maximum day/maximum hour (MGD)	212.61/N.A.



AQUEDUCT
SAN DIEGO
SECOND
AQUEDUCT
SAN DIEGO
FIRST
Lake Hodges Reservoir
City Limits
Sutherland Reservoir
City Limits
Miramar Reservoir
San Vicente Reservoir
El Capitan Reservoir
SAN DIEGO
City Limits
Mission Bay
Lake Murray Reservoir
Barrett Reservoir
PACIFIC OCEAN
N
Lower Otay Reservoir
City Limits
MEXICO

Figure 24. San Diego Water Utility reservoir system and service area.

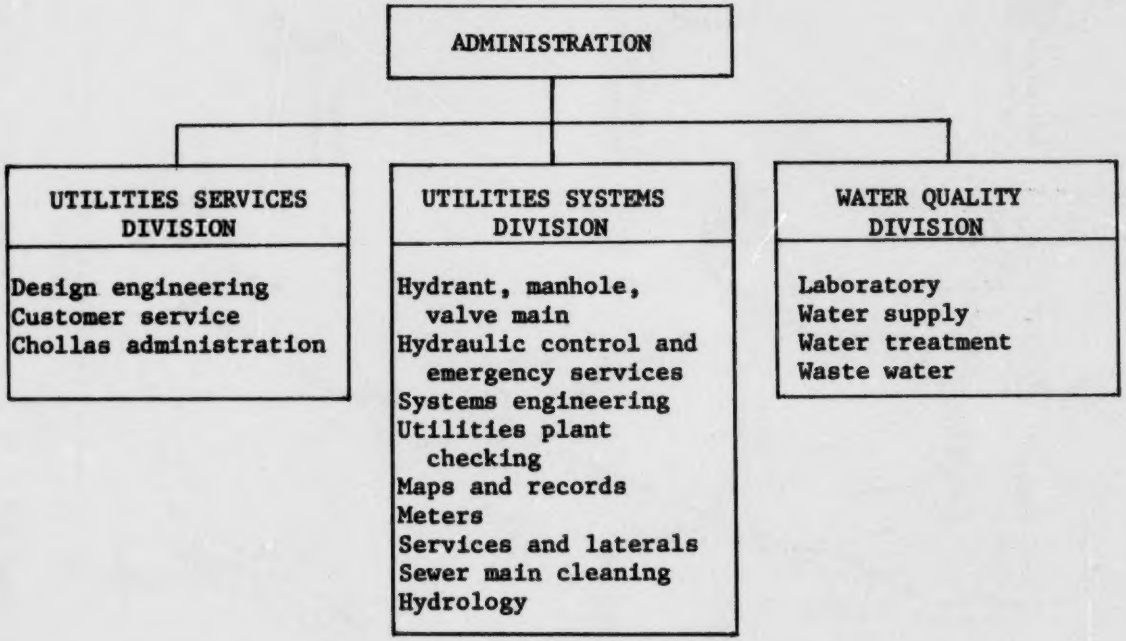

ADMINISTRATION
UTILITIES SERVICES DIVISION
Design engineering
Customer service
Chollas administration
UTILITIES SYSTEMS DIVISION
Hydrant, manhole, valve main
Hydraulic control and emergency services
Systems engineering
Utilities plant checking
Maps and records
Meters
Services and laterals
Sewer main cleaning
Hydrology
WATER QUALITY DIVISION
Laboratory
Water supply
Water treatment
Waste water

Figure 25. San Diego Water Utility organizational chart.

for water and sewer revenues and expenses. All bonds are clearly defined as either water or sewer bonds.

ACQUISITION

There are no permanent streams or natural lakes anywhere in the San Diego area, nor are there any extensive groundwater sources. For this reason, San Diego has developed a system of impounding reservoirs (Figure 24) divided into three geographical districts. Each series of watersheds or drainage basins extends from the summit of the mountains to the lowest dam. Parallel to the Mexican Border is the Cottonwood-Otay District, which includes Morena and Barrett reservoirs on the Cottonwood River, and the Dulgura Conduit and Upper and Lower Otay reservoirs on the Otay River.

To the north of the Cottonwood-Otay District lies the San Diego River, the largest river system in the county in terms of runoff. This watershed contains the Cuyomaca reservoir (which is owned by the Helix Irrigation District) and El Capitan and San Vicente reservoirs (owned by the City of San Diego). The San Dieguito River District, which includes Sutherland and Hodges reservoirs, is north of the Helix Irrigation District.

These reservoirs provide storage for local runoff and for imported water that flows down from the north through the two San Diego aqueducts. In 1974, 89.4% of the water used by the San Diego Water Utility was imported from the Colorado River. This percentage will drop as water is imported from the Feather River project in Northern California.

TREATMENT

Raw water treatment is accomplished by three treatment plants: the Alvarado plant, located at the Murray reservoir; the Miramar plant, located at Miramar reservoir; and the Otay plant, located at the Otay reservoir. The plants have a combined capacity of 66, 40, and 15 MGD, respectively.

The Alvarado treatment plant filters water that originates in the San Diego River system, including water originating from the El Capitan, San Vicente, and Murray reservoirs, and Colorado River water stored in the San Vicente and El Capitan reservoirs. Water from the San Diego aqueduct can also be processed at this plant.

The Miramar plant serves the northern section of the city and filters water transported from the Colorado River through the facilities of the Metropolitan Water District of Southern California and the San Diego County Water Authority. Miramar reservoir serves as a supplemental source of supply or in the event of an aqueduct failure.

The Otay plant serves the South Bay area of the city and treats water from the Cottonwood-Otay system and from the second San Diego aqueduct. Water from Morena and Barrett reservoirs is transferred to Otay when available and is treated after being pumped from the Otay reservoir.

The Alvarado, Miramar, and Otay treatment plants are similar in design, with separate mixing and settling basins with rapid sand filters. The Otay treatment plant combines the steps of mixing, coagulation, and sedimentation in one single basin and has pressure filters. Figure 26 is a flow diagram of the Alvarado plant.

TRANSMISSION AND DISTRIBUTION

The three treatment plants are located between 521 and 715 ft above sea level; however, most of the customers are located below these elevations and are supplied by gravity from the treatment plants. Pressure-reducing valves are required on trunk mains. The highest point in the distribution area is 1,020 ft above sea level. The higher elevations scattered throughout the distribution area are supplied through small pumping plants. Most of these areas are also equipped with elevated storage tanks or standpipes for the purpose of leveling out demand. There are currently 145 pressure-reducing stations, 33 pumping stations, 23 elevated storage tanks, and 74 pressure zones in the San Diego system.

The distribution storage reservoirs are built at strategic locations, allowing the filtration plants to be operated at a fairly constant rate. During periods of peak demand, the water flows back out of the reservoirs and augments the filtration plants. The system now has 20 covered storage reservoirs with a total capacity of 159.37 mil gal.

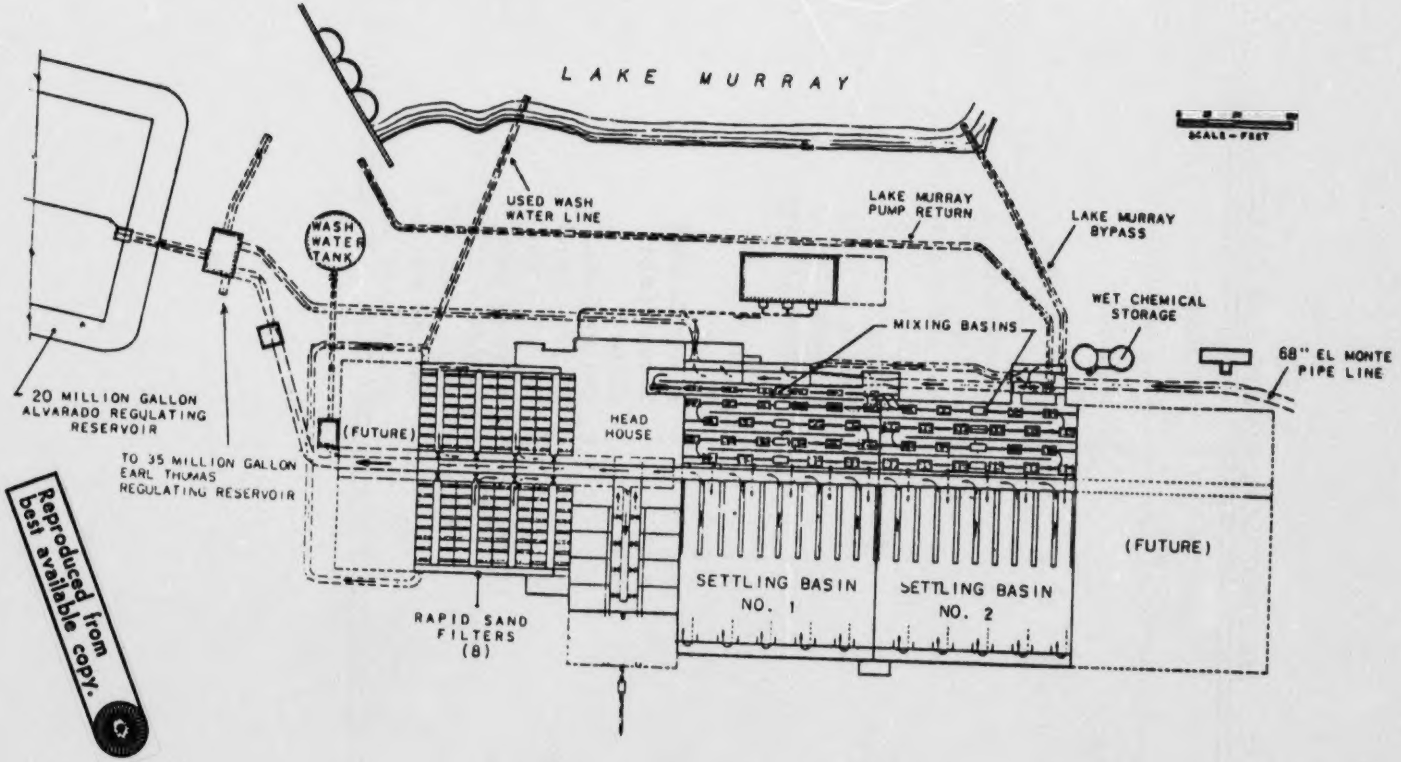
The standpipes and elevated storage tanks within the San Diego system serve a dual purpose--leveling out the demand on the pumping plants and maintaining adequate delivery pressures within the higher elevations of the distribution area. At present, there are 10 standpipes with a total storage capacity of 13.28 mil gal and 11 tanks with a total capacity of 3.05 mil gal in the San Diego system. Table 50 is a summary sheet of the facilities making up the storage system.

COST ANALYSIS

Figure 27 illustrates the steady growth in the production of water from 1965 through 1974. The cost analysis for each utility is based on RPW. Unit costs have been calculated by dividing cost for a given functional area by the amount of RPW supplied.

Tables 51, 52, and 53 contain the costs for treatment, acquisition, transmission and distribution, power and pumping, and support services. The "other" category under support services includes expenses of other city departments that relate to the water utility, contributions to the retirement fund, compensation insurance, other insurance and damage claims, uncollectable accounts, engineering, taxes, and general expenses.

Table 54 is an analysis of labor costs for San Diego and shows that although the unit cost of water based on labor input is rising, the number of manhours required to produce a million gallons is decreasing. Table 55 shows


LAKE MURRAY
SCALE—FEET
USED WASH WATER LINE
LAKE MURRAY PUMP RETURN
LAKE MURRAY BYPASS
WASH WATER TANK
WET CHEMICAL STORAGE
MIXING BASINS
68" EL MONTE PIPE LINE
20 MILLION GALLON ALVARADO REGULATING RESERVOIR
TO 35 MILLION GALLON EARL THOMAS REGULATING RESERVOIR
(FUTURE)
HEAD HOUSE
RAPID SAND FILTERS (8)
SETTLING BASIN NO. 1
SETTLING BASIN NO. 2
(FUTURE)

Reproduced from best available copy.

Figure 26. Flow diagram of the Alvarado filtration plant (Water Utilities Department, City of San Diego).

TABLE 50. SAN DIEGO WATER UTILITY STORAGE FACILITIES

Facility	Capacity (mil gal)	Facility	Capacity (mil gal)
Reservoirs (covered):		Standpipes:	
Alvarado	20.2	Camp Callan	2.0
Bayview	10.0	Catalina	1.5
Brown Field	1.0	Chesterton	0.99
Del Cerro	1.5	College Ranch	1.5
Earl Thomas	35.0	Emerald Hills	1.5
La Jolla CC Hts	0.5	Encanto	0.75
La Jolla Exchange	.99	Kearney Mesa	1.52
La Jolla View	.72	Lomita Village	0.77
Miramar Reg	20.0	Paradise Hills	0.75
Pacific Beach	2.4	Redwood Village	2.0
Point Loma	10.06		
Pomerado Park	5.2	Tanks:	
Penasquitos	5.0		
Rancho Bernardo	10.1	Alvarado Wash	0.792
San Carlos	5.0	Brown Field	---
San Ysidro	1.2	Climax	0.002
Soledad	1.5	College Hts.	0.50
South San Diego	15.0	College Ranch	---
Torrey Pines	2.8	La Jolla CC	0.003
University Hts.	11.2	Miramar Wash	0.50
		Paradise Hills #2	.003
		Point Loma Sewage	.050
		San Carlos	.002
		University Hts.	1.200

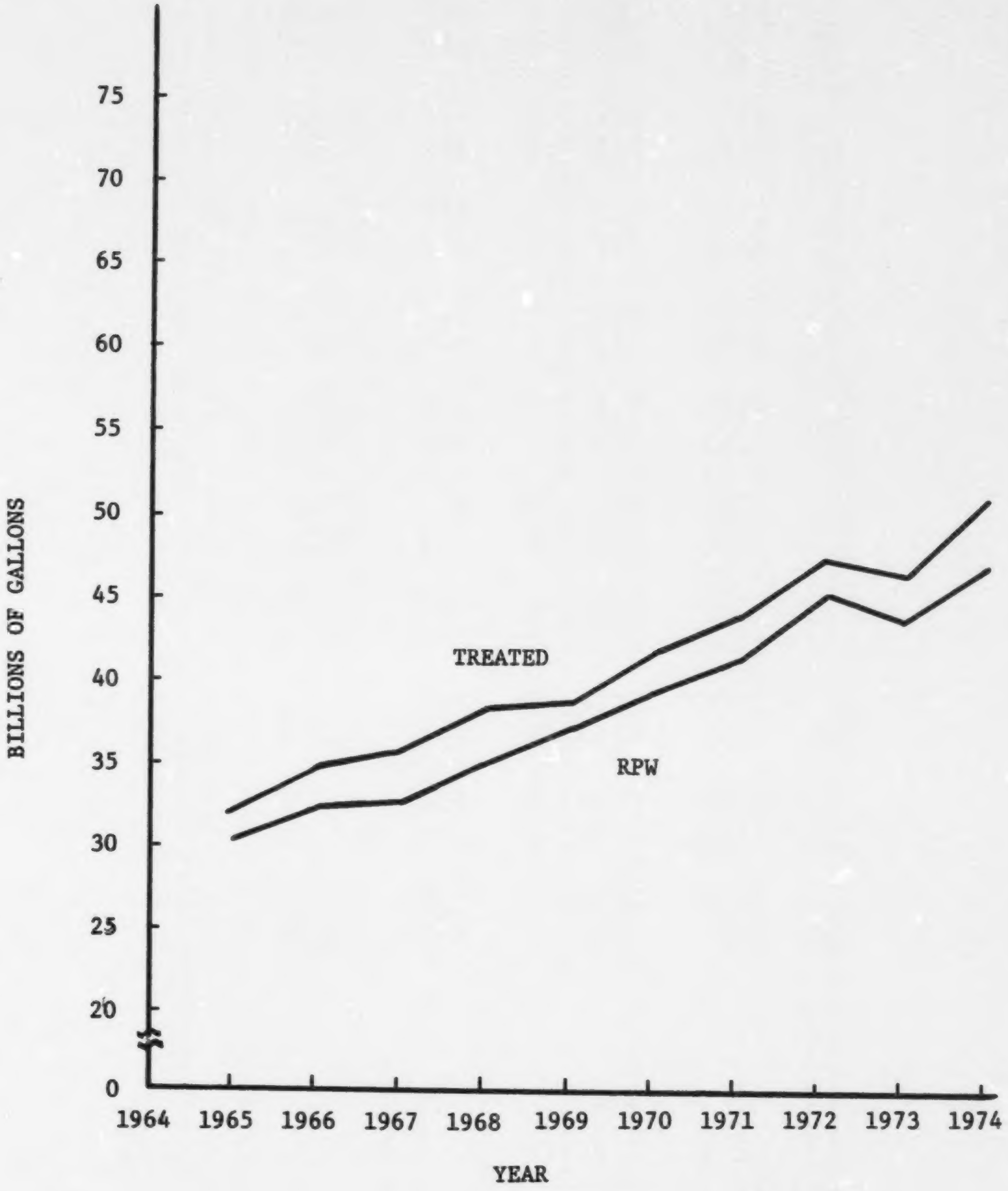


Figure 27. San Diego Water Utility water flow: treated water versus RPW.

TABLE 51. SAN DIEGO WATER UTILITY ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$ 367,863	$ 325,079	$ 384,750	$ 418,357	$ 463,869	$ 207,538	$ 224,967	$ 229,958	$ 238,638	$ 251,425
Accounting and collection	370,697	426,691	511,013	515,851	700,219	729,688	710,393	736,689	891,761	1,016,043
Other	918,736	959,086	1,077,771	1,277,882	1,510,889	1,829,757	2,150,856	2,321,519	2,730,463	3,151,995
Total support sercices	1,657,296	1,710,856	1,973,534	2,212,090	2,674,977	2,766,983	3,086,216	3,288,166	3,860,862	4,419,463
Acquisition:										
In lieu of taxes and payments	1,728,586	1,876,458	1,810,262	1,860,094	3,248,161	3,723,339	4,119,568	4,851,837	5,063,372	5,335,690
Purchase of water	2,883,918	2,609,532	2,940,944	3,578,306	4,468,675	4,361,873	4,996,429	7,164,875	8,793,815	7,026,638
Impounding/transmission	491,060	481,999	387,537	416,087	496,109	556,099	535,124	595,165	566,241	567,396
Other	138,905	172,797	234,227	130,223	-	-	-	-	-	-
Total acquisition	5,242,469	5,140,786	5,372,970	5,984,710	8,212,945	8,641,311	9,651,121	12,611,877	14,423,428	12,929,724
Treatment:	533,115	519,532	492,548	539,065	641,455	725,262	747,559	806,348	913,471	1,055,868
Power and pumping:										
Pumping	137,201	150,444	161,308	154,143	156,045	176,233	182,055	230,279	247,521	286,130
Other	20,367	20,499	25,034	22,802	24,310	35,738	49,520	50,961	52,312	59,646
Total power and pumping	157,568	170,943	186,342	176,945	180,355	211,970	231,575	281,240	299,833	345,776
Transmission and distribution:										
Mains	735,668	722,331	780,076	823,365	839,388	831,956	750,927	845,835	872,818	829,755
Services	263,070	296,901	254,223	242,644	303,581	246,315	284,585	307,020	341,075	347,245
Meters	530,141	451,292	403,633	535,480	496,501	410,400	486,078	582,627	608,068	671,878
Reservoirs and tanks	58,052	91,288	93,937	95,440	87,062	85,205	81,787	96,143	104,865	100,143
Other	280,117	249,610	286,003	298,567	323,098	409,434	617,586	535,013	530,370	528,999
Total transmission & distribution	1,867,048	1,811,422	1,817,872	1,995,496	2,049,630	1,983,310	2,220,963	2,366,638	2,457,196	2,478,020
Total operating cost	9,457,496	9,353,539	9,843,266	10,908,306	13,759,362	14,328,836	15,937,434	19,354,269	21,954,790	21,228,851

TABLE 52. SAN DIEGO WATER UTILITY OPERATING COSTS/($/MIL GAL RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	12.11	10.01	11.72	11.92	12.43	5.20	5.37	5.06	5.45	5.33
Accounting and collection	12.20	13.14	15.56	14.70	18.76	18.30	16.96	16.20	20.38	21.52
Other	30.25	29.54	32.82	36.42	40.47	45.89	51.34	51.04	62.39	66.77
Total support services	54.56	52.69	60.09	63.05	71.66	69.39	73.67	72.29	88.22	93.62
Acquisition:										
In lieu of taxes and payments	56.91	57.79	55.12	53.02	87.01	93.38	98.33	106.67	115.70	113.03
Purchase of water	94.95	80.37	89.55	101.99	119.71	109.39	119.26	157.53	200.94	148.85
Impounding/transmission	16.17	14.85	11.80	11.86	13.29	13.95	12.77	13.09	12.94	12.02
Other	4.57	5.32	7.13	3.71	-	-	-	-	-	-
Total acquisition	172.60	158,33	163.60	170.57	220.01	216.72	230.37	277.28	329.57	273.91
Treatment:	17.55	16.00	15.00	15.36	17.18	18.19	17.84	17.73	20.87	22.37
Power and pumping:										
Pumping	4.52	4.63	4.91	4.39	4.18	4.42	4.35	5.06	5.66	6.06
Other	0.67	0.63	0.76	0.65	0.65	0.90	1.18	1.12	1.20	1.26
Total power and pumping	5.19	5.26	5.67	5.04	4.83	5.32	5.53	6.18	6.85	7.32
Transmission and distribution:										
Mains	24.22	22.25	23.75	23.47	22.49	20.86	17.92	18.60	19.94	17.58
Services	8.66	9.14	7.74	6.92	8.13	6.18	6.79	6.75	7.79	7.36
Meters	17.45	13.90	12.29	15.26	13.30	10.29	11.60	12.81	13.89	14.23
Reservoirs and tanks	1.91	2.81	2.83	2.72	2.33	2.14	1.95	2.11	2.40	2.12
Other	9.22	7.69	8.71	8.51	8.66	10.27	14.74	11.76	12.12	11.21
Total transmission and distribution	61.47	55.79	55.35	56.87	54.91	49.74	53.01	52.03	56.15	52.49
Total operating cost	311.38	288.08	299.72	310.89	368.59	359.35	380.42	425.51	501.66	449.72

The above figures are not additive. They are obtained by dividing yearly mil gal RPW into the annual costs shown in the preceding Table.

TABLE 53. SAN DIEGO WATER UTILITY OPERATING COST CATEGORIES AS A PERCENT OF TOTAL OPERATING COST

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	3.89	3.48	3.91	3.84	3.37	1.45	1.41	1.19	1.09	1.18
Accounting and collection	3.91	4.56	5.19	4.73	5.09	5.09	4.46	3.81	4.06	4.79
Other	9.72	10.25	10.95	11.71	10.98	12.77	13.50	11.99	12.43	14.85
Total support services	17.52	18.29	20.05	20.28	19.44	19.31	19.36	16.99	17.58	20.82
Acquisition:										
In lieu of taxes and payments	18.27	20.06	18.39	17.05	23.61	25.98	25.85	25.07	23.06	25.13
Purchase of water	30.50	27.90	29.88	32.80	32.48	30.44	31.35	37.02	40.05	33.10
Impounding/transmission	5.19	5.15	3.94	3.81	3.61	3.88	3.36	3.08	2.58	2.67
Other	1.47	1.85	2.38	1.19	-	-	-	-	-	-
Total acquisition	55.43	54.96	54.59	54.86	59.69	60.31	60.56	65.16	65.70	60.91
Treatment:	5.64	5.55	5.00	4.94	4.66	5.06	4.69	4.17	4.16	4.97
Power and pumping:										
Pumping	1.45	1.61	1.64	1.41	1.13	1.23	1.14	1.19	1.13	1.35
Other	0.22	0.22	0.25	0.21	0.18	0.25	0.31	0.26	0.24	0.28
Total power and pumping	1.67	1.83	1.89	1.62	1.31	1.48	1.45	1.45	1.37	1.63
Transmission and distribution:										
Mains	7.78	7.72	7.92	7.55	6.10	5.81	4.71	4.37	3.98	3.91
Services	2.78	3.17	2.58	2.23	2.21	1.72	1.79	1.59	1.55	1.64
Meters	5.61	4.82	4.10	4.91	3.61	2.86	3.05	3.01	2.77	3.16
Reservoirs and tanks	0.61	0.98	0.95	0.87	0.63	0.59	0.51	0.50	0.48	0.47
Other	2.96	2.67	2.91	2.74	2.35	2.86	3.88	2.76	2.42	2.49
Total transmission and distribution	19.74	19.37	18.47	18.30	14.90	13.84	13.94	12.23	11.19	11.67
Total operating cost	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 54. SAN DIEGO WATER UTILITY LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)*	2,553,524	2,525,456	2,657,682	2,945,243	3,715,028	3,868,786	4,303,107	5,225,653	6,010,371	6,323,384
Total hours on payroll †	841,781.3	867,973.0*	844,954.9*	821,936.7	1,050,737.8	1,045,416.0	1,046,527.4	1,057,132.7	1,051,336.9	1,045,541.0
RPW (mil gal)	30,373	32,468	32,842	35,086	37,330	39,874	41,894	45,484	43,764	47,205
Total payroll/mil gal RPW	87.07	77.78	80.92	83.94	99.52	97.03	102.71	114.89	137.34	133.96
Total hours/mil gal RPW	27.71	26.73	19.95	23.43	28.15	26.22	24.98	23.24	24.02	22.15
Average cost/man-hour ($) †	3.03	2.91	3.15	3.58	3.54	3.70	4.11	4.94	5.72	6.05

* Includes operation and maintenance payroll only.

† Includes all water utility man-hours.

TABLE 55. SAN DIEGO WATER UTILITY CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expenses	$ 9,457,496	$ 9,353,539	$ 8,843,266	$10,908,306	$13,759,362	$14,328,836	$15,937,434	$19,354,269	$21,954,790	$21,228,851
Depreciation	2,572,669	2,496,354	2,526,851	2,676,098	2,627,145	2,811,573	2,532,092	2,768,889	2,578,850	2,778,632
Interest	664,684	621,896	580,202	539,381	498,747	459,194	421,966	385,204	350,645	317,516
Total	12,694,849	12,471,789	12,950,319	14,123,785	16,885,254	17,599,603	18,891,492	22,508,362	24,884,285	24,324,999
Total unit cost/ mil gal RPW	417.96	384.13	394.32	402.55	452.32	441.38	450.94	494.86	568.60	515.31

operating and capital cost expenditures, and Table 56 gives the percent of operating and capital cost as a function of total cost.

SYSTEM COSTS

The cost of each functional component of the San Diego Water Utility can be reaggregated and allocated against the physical components of the water delivery system. The arrows in Figure 28 show the direction of the flow of water from the treatment plants through booster pumping stations and pressure regulators to the 74 service areas across the city.

Operation and depreciation costs for each component of the system are shown in Figure 29. Total delivery costs of water to specific points within the distribution area are given in Table 57.

Table 58 establishes the monthly unit cost for water consumption in San Diego based on meter size and typical consumption rates. Most domestic, commercial, and industrial customers are billed bimonthly, although 5,000 customers are billed monthly.

Table 59 shows the six major customers of the San Diego Water Utility together with their high and low water use, the number of million gallons used during that time, and the amount they were billed for the service. These same users (Figure 30) are all located on the shores of San Diego Bay with the exception of the Torrey Pines Golf Course. The cost zones established for the San Diego Utility are also shown in Figure 30.

Table 60 compares the costs associated with delivery of water to the consumer versus the costs actually paid.

Average unit costs for all water supplied during the most recent year studied are given as follows:

	$/mil gal
Support services------	96
Acquisition-----------	277
Treatment-------------	28
Distribution----------	106
Interest--------------	7
Total-----------------	514

TABLE 56. SAN DIEGO WATER UTILITY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating cost ($)	9,457,496	9,353,539	9,843,266	10,908,306	13,759,362	14,328,836	15,937,434	19,354,269	21,954,790	21,228,851
Capital cost ($)	3,237,353	3,118,250	3,107,053	3,215,479	3,125,892	3,270,767	2,954,058	3,154,093	2,929,495	3,096,148
Total cost ($)	12,694,849	12,471,789	12,950,319	14,123,785	16,885,254	17,599,603	18,891,492	22,508,362	24,834,285	24,324,999
Operating cost as % of total	74.50	75.00	76.01	77.23	81.49	81.42	84.36	85.99	88.23	87.27
Capital cost as % of total	25.50	25.00	32.99	22.77	18.51	18.58	15.64	14.01	11.77	12.73

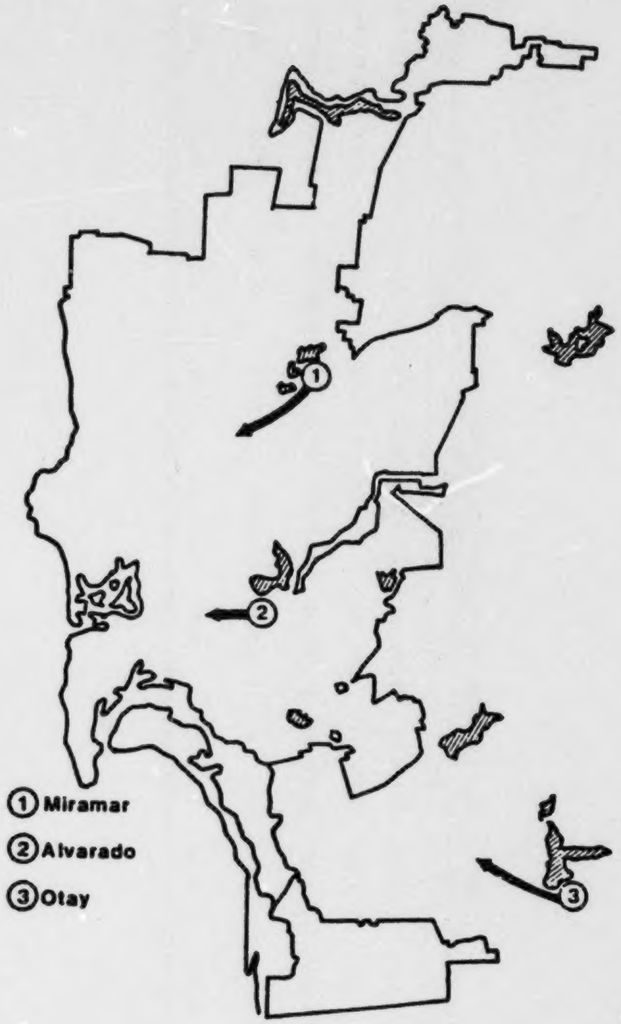

① Miramar
② Alvarado
③ Otay
1
2
3

Figure 28. San Diego Water Utility facilities (arrows indicate general direction of water flow).

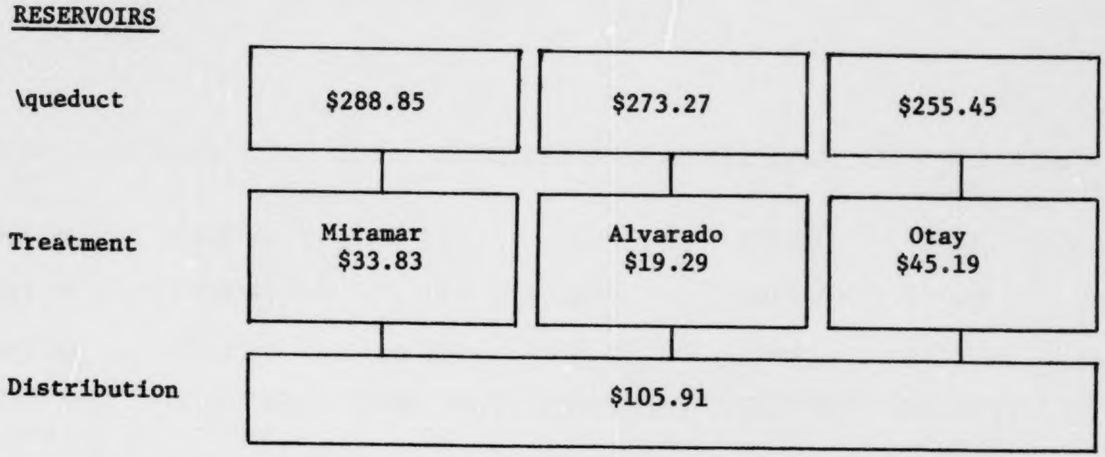

RESERVOIRS
Aqueduct
$288.85
$273.27
$255.45
Treatment
Miramar $33.83
Alvarado $19.29
Otay $45.19
Distribution
$105.91

Figure 29. San Diego Water Utility capital and operating costs allocated to water system components ($/mil gal RPW).

TABLE 57. COST ELEMENTS FOR SAN DIEGO SERVICE ZONES

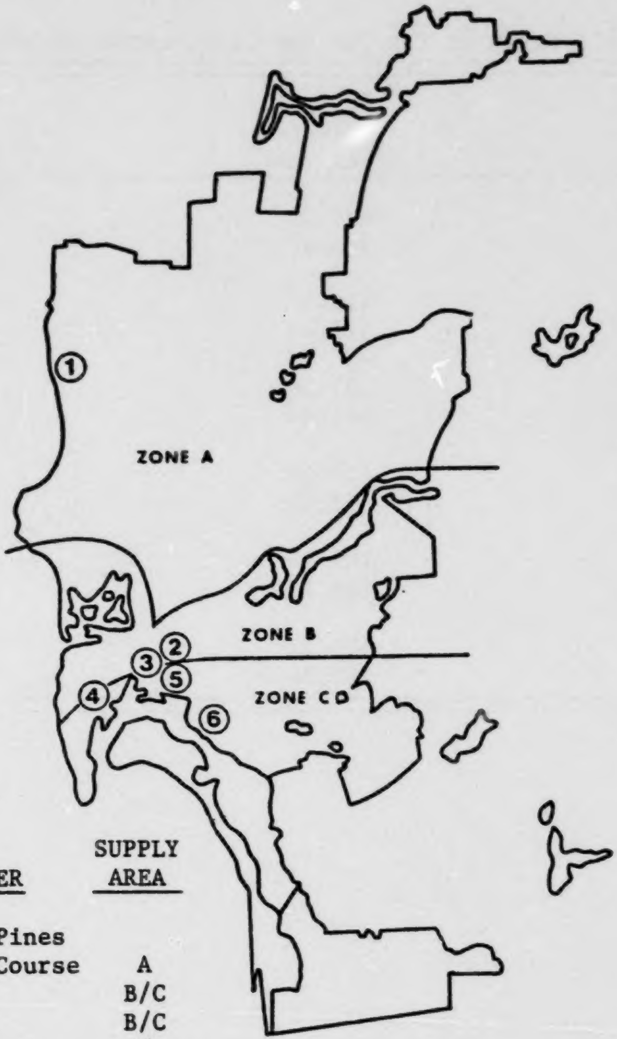
Pathway No.	Incremental cost ($/mil gal)	Distribution cost ($/mil gal)	Interest ($/mil gal)	Overhead ($/mil gal)	Total cost ($/mil gal)	RPW (mil gal)	Revenue
1	322.68	105.91	6.73	95.67	530.99	17,013	$9,033,732.87
2	292.56	105.91	6.73	95.67	500.87	24,802	12,422,577.74
3	300.64	105.91	6.73	95.67	508.95	5,377	2,736,624.15
Total	---	---	---	---	---	47,192	24,192,934.76

TABLE 58. TYPICAL MONTHLY RATES FOR SAN DIEGO WATER UTILITIES

Class	Meter size (in.)	Gallons consumed	Amount billed	Unit cost ($/mil gal)
Residential	5/8	10,000	$3.91	$391.00
Commercial	4	1,000,000	490.32	490.32
Industrial	10	25,000,000	10,158.05	406.32

TABLE 59. SAN DIEGO WATER UTILITY WATER COSTS FOR 6 MAJOR USERS

Major user	High or low month	Month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Cost zone
Kelco Co.	High	Aug.	16.3	$6,583	$404.36	C
	Low	Dec.	7.5	3,134	420.67	
Navy Training	High	Dec.	25.0	10,376	414.37	B/C
	Low	Jan.	5.0	2,542	511.46	
USMC	High	Sept.	46.5	18,743	403.36	C
	Low	Aug.	18.4	7,765	423.16	
Convair	High	June	7.1	2,995	422.42	B
	Low	Dec.	3.3	1,524	459.03	
Solar Aircraft	High	June	15.2	6,167	405.19	B
	Low	July	6.8	2,890	423.75	
Torrey Pines	High	July	11.6	4,959	429.35	A
	Low	Jan.	1.2	923	762.80	


①
ZONE A
ZONE B
②
③
⑤
④
ZONE C
⑥

MAJOR USER	SUPPLY AREA
1 Torrey Pines Golf Course	A
2 Solar	B/C
3 Convair	B/C
4 NTC	B/C
5 USMC	B/C
6 Kelco	C

Figure 30. San Diego Water Utility major users and cost zones.

TABLE 60. COSTS AND REVENUES FOR THE SAN DIEGO WATER UTILITY'S 6 MAJOR USERS

Major user	Revenue collected ($/mil gal)	Delivery cost ($/mil gal)
Kelco Co.	$404.36	$515.86
	420.67	
Navy Training	414.37	505.21
	511.46	574.11
USMC	403.36	505.21
	423.16	574.11
Convair	422.42	505.21
	459.03	574.11
Solar Aircraft	405.19	503.21
	423.75	574.11
Torrey Pines	429.35	574.11
	762.80	

SECTION 9

NEW HAVEN WATER COMPANY

The New Haven Water Company provides water to the City of New Haven, Connecticut, and surrounding communities. The 1973 population served by the water company was 371,144. Ninety-five percent of the customers are metered. Over a 10-year period, there was an approximate 16% increase in water concumption, partly because of the acquisition of the Milford Water Company in 1966. Some systems facts are shown in Table 61.

The New Haven Water Company is an investor-owned utility and as such has some different characteristics from the majority of the utilities in this report, which are operated by counties or municipalities. One basic difference is that this utility incurs a liability for real estate and other taxes not incurred by publicly owned utilities.

WATER SUPPLY SERVICE AREA

The New Haven Water Company provides water on a retail basis to all classes of customers within the service area shown in Figure 31. Treated water is supplied to all or part of 12 towns. The major town in the service area is New Haven. As noted above, population and water consumption increased slightly over the 10-year period; but since 1966, water consumption has remained relatively stable.

ORGANIZATION

Although the utility does run a small forestry operation in the watershed, it operates as a system for the purpose of supplying water only and is not associated with any other organization. The water company is headed by a 12-member board of directors and is operated by the president who is a member of the board.

Four divisions report to the president (Figure 32): one is responsible for the engineering effort, one for the accounting and collection, one for all administration, and one for the operations of the system, including maintenance and meter reading.

ACQUISITION

Raw water comes from a series of reservoirs and wells. Approximately 5% of the total water is from the wells. Most of the reservoirs are located

TABLE 61. NEW HAVEN WATER COMPANY, BASIC FACTS.

Item	Amount
Population:	
SMSA	N.A.
County	N.A.
Retail Service Area	371,144
Area of retail service area (square miles)	316
Number of metered customers	84,167
Percent metered	95.4
Flat rate customers	4,104
Purchased water	None
Source water:	
Percent surface	95.6
Percent wells	4.4
Miles of Pipe in system	1,266
Elevation of treatment plant (ft above mean sea level):	
Whitney	30
Saltonstall	50
Elevation of service area (ft above mean sea level) min - max	0 - 525
Revenue-producing water (mil gal)	17,714
Treated Water (mil gal pumpage from treatment plants)	20,300
Max day/max hour - July 4, 1974 (MGD)	78.8/98.52

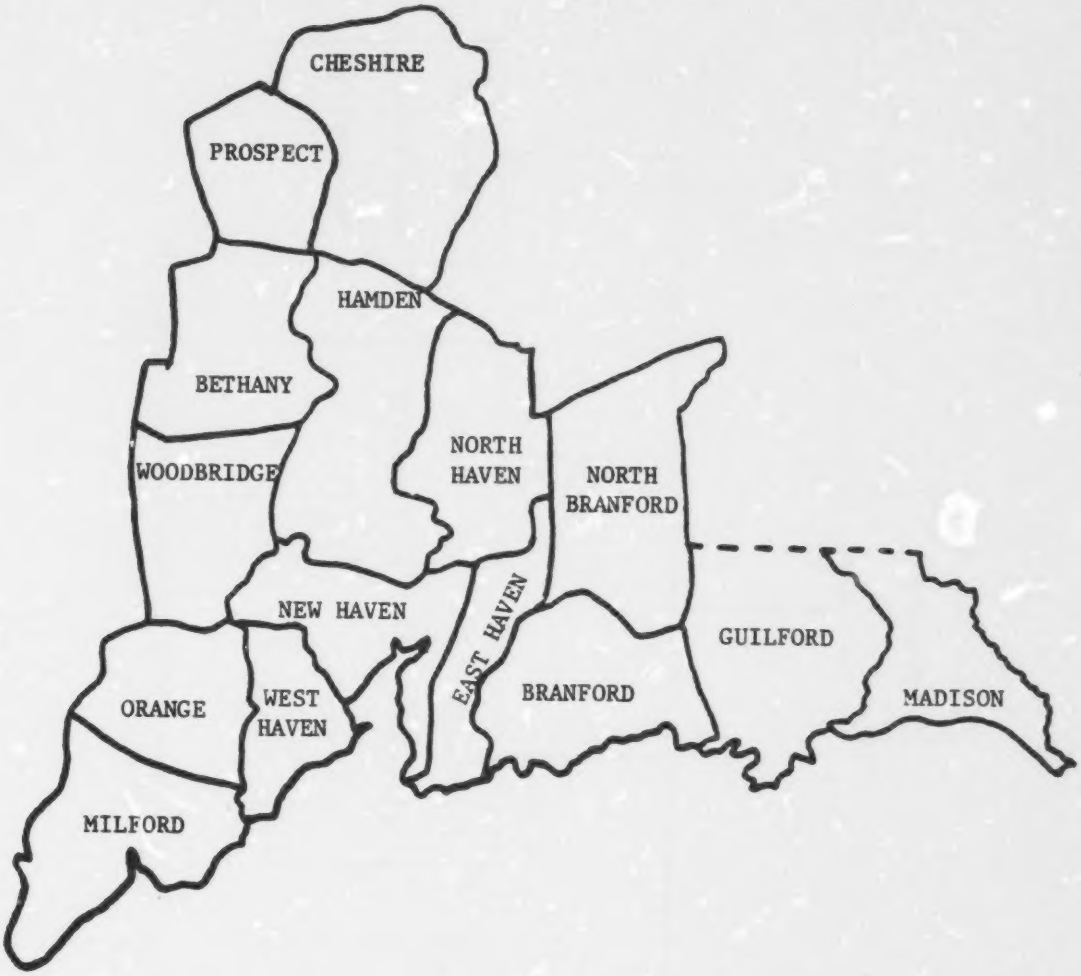

CHESHIRE
PROSPECT
HAMDEN
BETHANY
WOODBRIDGE
NORTH HAVEN
NORTH BRANFORD
NEW HAVEN
EAST HAVEN
GUILFORD
ORANGE
WEST HAVEN
BRANFORD
MADISON
MILFORD

Figure 31. New Haven Water Company service area.

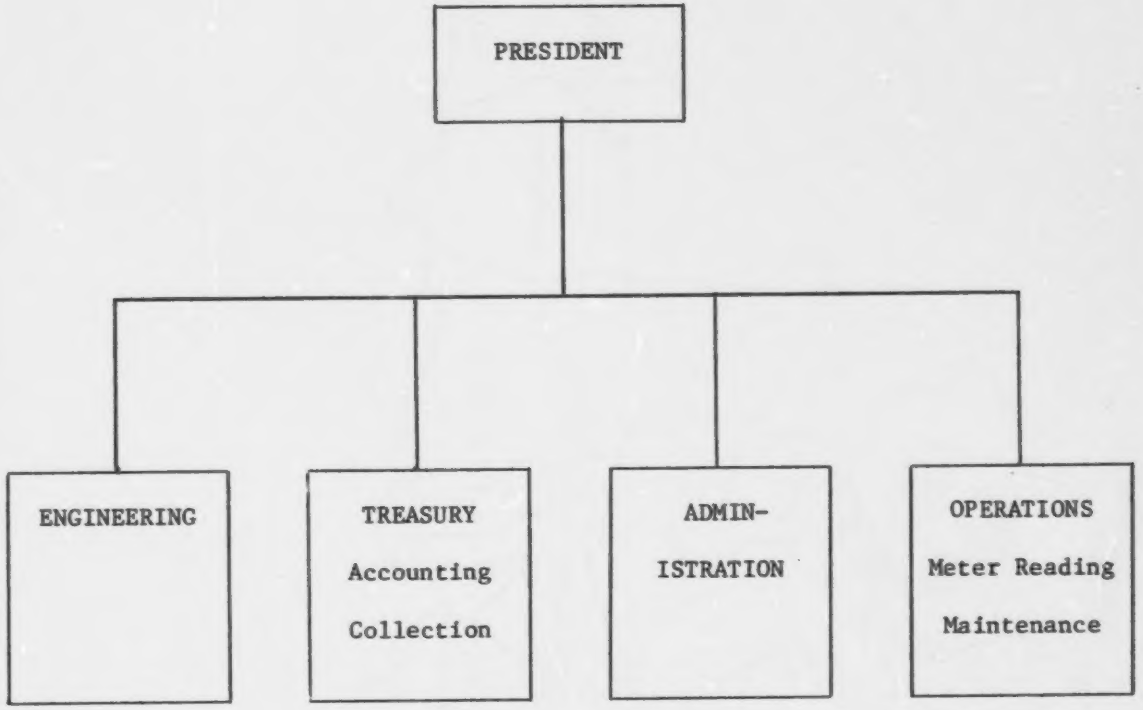

PRESIDENT
ENGINEERING
TREASURY
Accounting
Collection
ADMIN-
ISTRATION
OPERATIONS
Meter Reading
Maintenance

Figure 32. New Haven Water Company organizational chart.

within the service area, and others are located in townships to the east of the service area.

The company owns 26,000 acres of land located in 17 communities in Connecticut. Most of this land is associated with the reservoirs. All reservoirs are surrounded by a greenbelt and are fenced to control access. Rather than invest their money in treatment operations, the water company chose to invest in developing a quality water acquisition system that would require less treatment. Restoration of the area is a continuing vital part of the land operations, and this involves obtaining some lumber from the area around the reservoirs. Most of the logging, however, is a result of the trees becoming diseased. Revenues received from the operation help to lower the water rates charged to consumers.

Nine major intake facilities associated with the reservoir system and three intake facilities associated with well fields are geographically distributed over the service area, thus minimizing the transmission of potable water within the system.

The large land holdings result in sizable real estate property taxes. The company indicated it is considering the sale of some 16,500 acres not necessary to the water utility. The reason for this is that natural land filtration will no longer be adequate to provide water that meets the new and more stringent State and Federal water standards. Because water will have to be treated by filtration and other processes, the large holdings around the reservoirs are less desirable.

TREATMENT

As indicated, the company provides high quality source water naturally filtered. Chlorine is added as disinfectant at the various reservoir intakes and wells scattered throughout the system. Two small filter plants presently in operation filter approximately 7% of the reservoir water.

The New Haven Water Company recognizes that natural land filtration will not provide water of adequate quality to meet the standards presently under consideration. Because of this, the need for ownership of watershed lands is eliminated, and plans are underway to mechanically filter water at various treatment plants. One such plant is under construction at Lake Saltonstall in East Haven for an estimated $5.5 million. Additional plants are anticipated to be operational within the next few years. Figure 33 shows locations of wells and treatment facilities.

Most of the source of supply is at a slightly higher elevation than the distribution area. In 1973, only 25.1% of the total draft was pumped from the source. All of the water pumped from reservoirs was pumped from Lake Whitney at the low service pumping station.

At present, only one slow sand filtration plant located at Lake Whitney is in operation, and it filters 12 MGD from that source only. An additional filtration plant with an 8-MGD capacity is under construction at Lake Saltonstall.

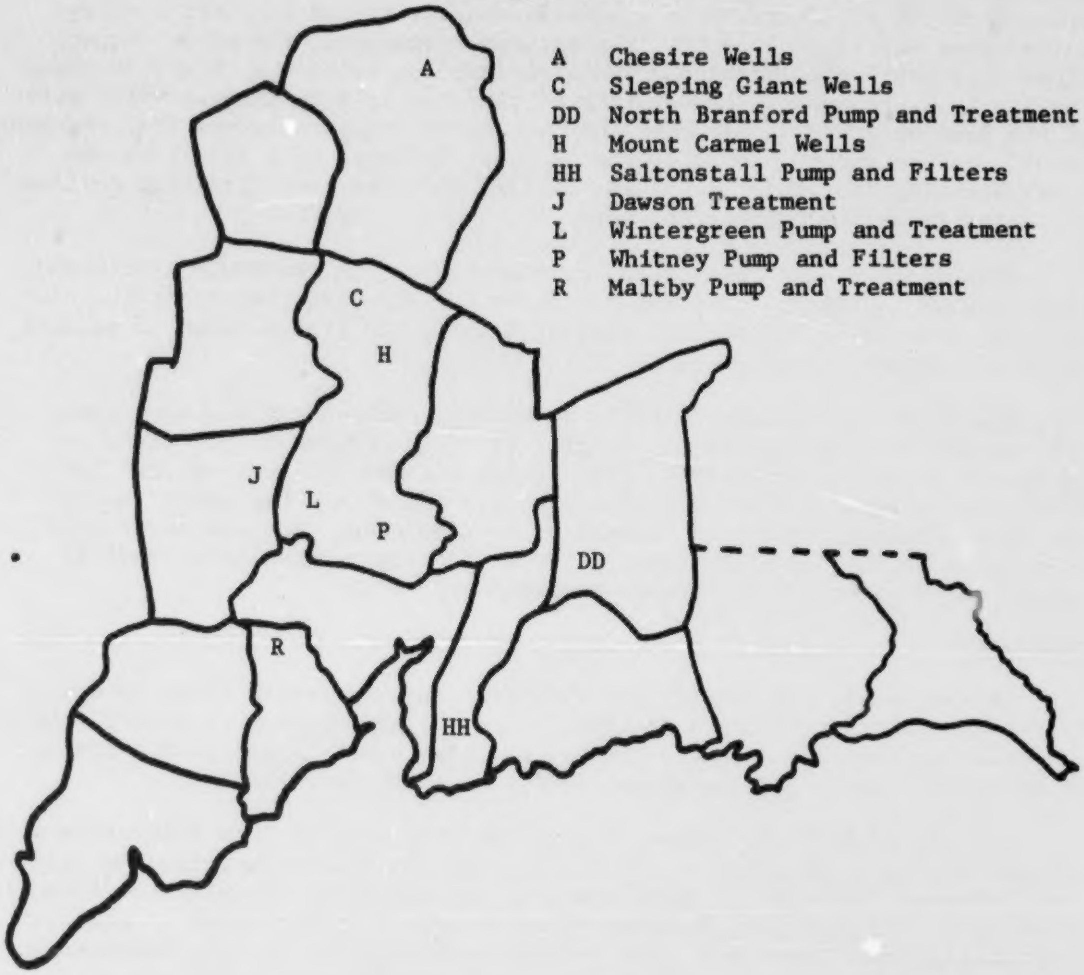

A Chesire Wells
C Sleeping Giant Wells
DD North Branford Pump and Treatment
H Mount Carmel Wells
HH Saltonstall Pump and Filters
J Dawson Treatment
L Wintergreen Pump and Treatment
P Whitney Pump and Filters
R Maltby Pump and Treatment
A
C
H
J
L
P
DD
R
HH

Figure 33. New Haven Water Company treatment facility locations.

All water is chlorinated at any one of 10 points as it is drawn from the reservoir system, or as it leaves either of the two well fields. Rechlorination takes place at the Spring Street station. In 1973, a total of 3,099 mil gal was rechlorinated at this site. Secondary chlorination of the distribution storage reservoirs also takes place. Calgon is added to the water at 11 points to reduce corrosion in the pipes. Fluoride is added at 12 points in the system, as required by State law.

TRANSMISSION AND DISTRIBUTION

The distribution system consists of 24 pumping stations, including those at the well sites, one storage reservoir, and 16 standpipes. The system is actually a number of small systems interconnected. The distribution reservoir and the standpipes have a total capacity of just over 3 mil gal. Table 62 identifies the distribution system's reservoir and standpipes and gives the capacity of each. There are 1,266 miles of pipe in the ground, ranging in size from 1 to 72 in.

COST ANALYSIS

Growth of consumer demand for water from 1964 through 1973 is illustrated in Figure 34. During the 10-year period there was only a slight increase in the amount of water used, and for the most part, that increase occurred with the acquisition of a small water utility in the 1966-67 time frame.

Using standard cost categories, data were collected and reported as shown in Tables 63, 64, and 65. Because a major portion of the operating budget was expended for labor, Table 66 was developed to examine labor costs for operation and maintenance activities. Because accurate man-hours were not available for the 5 years before 1969, that information is not part of this report.

Based on the records for 1969 through 1973, the cost for each man-hour increased 43%, and the amount of labor required to produce 1 mil gal increased by 32%. The increase in both these parameters reflects a rapid increase in the cost of producing water because there is a compounding relationship. For example, to produce 1 mil gal water in 1973 required 185.5 man-hours; in 1969, only 141.06 man-hours were required. In addition, a corresponding increase from $3.80 to $4.82/man-hour compounded the cost increase. The payroll and man-hours reflected in Table 66 include construction labor capitalized by the utility. The number of capitalized dollars, including both labor and materials, are identified in Tables 63, 64, and 65 and are removed from the total operating cost in subsequent areas of the report.

Table 67 summarizes operating and capital costs for the 10-year period of analysis. Table 68 computes capital and operating expenditure ratios. Operating expenses are those shown as the total of the values in Table 63, expenses incurred in the normal day-to-day operation of the system. The capital expenses are the total expenditures for providing major equipment items and facilities plus the interest charged on money borrowed for these purposes. A comparison of the operating expenses and the capital expenses

TABLE 62. NEW HAVEN WATER COMPANY DISTRIBUTION RESERVOIR AND STANDPIPES.

Location	Capacity (1,000 gallons)
Reservoir:	
Mill Rock*	8,660
Standpipes:	
Mill Rock	375
Burwell Hill	937
Burwell Hill	720
Shingle Hill*	720
Shingle Hill	2,000
Mount Carmel (2)	1,300
Summit Street	480
Rabbit Rock	1,000
Brushy Plains	1,000
High Rock	1,000
Naugatuck Avenue	800
Clark Hill	800
York Hill	2,500
Ford Street	2,100
Prospect Tank	2,500
North Branford	3,300
Total	30,192

* Open storage.

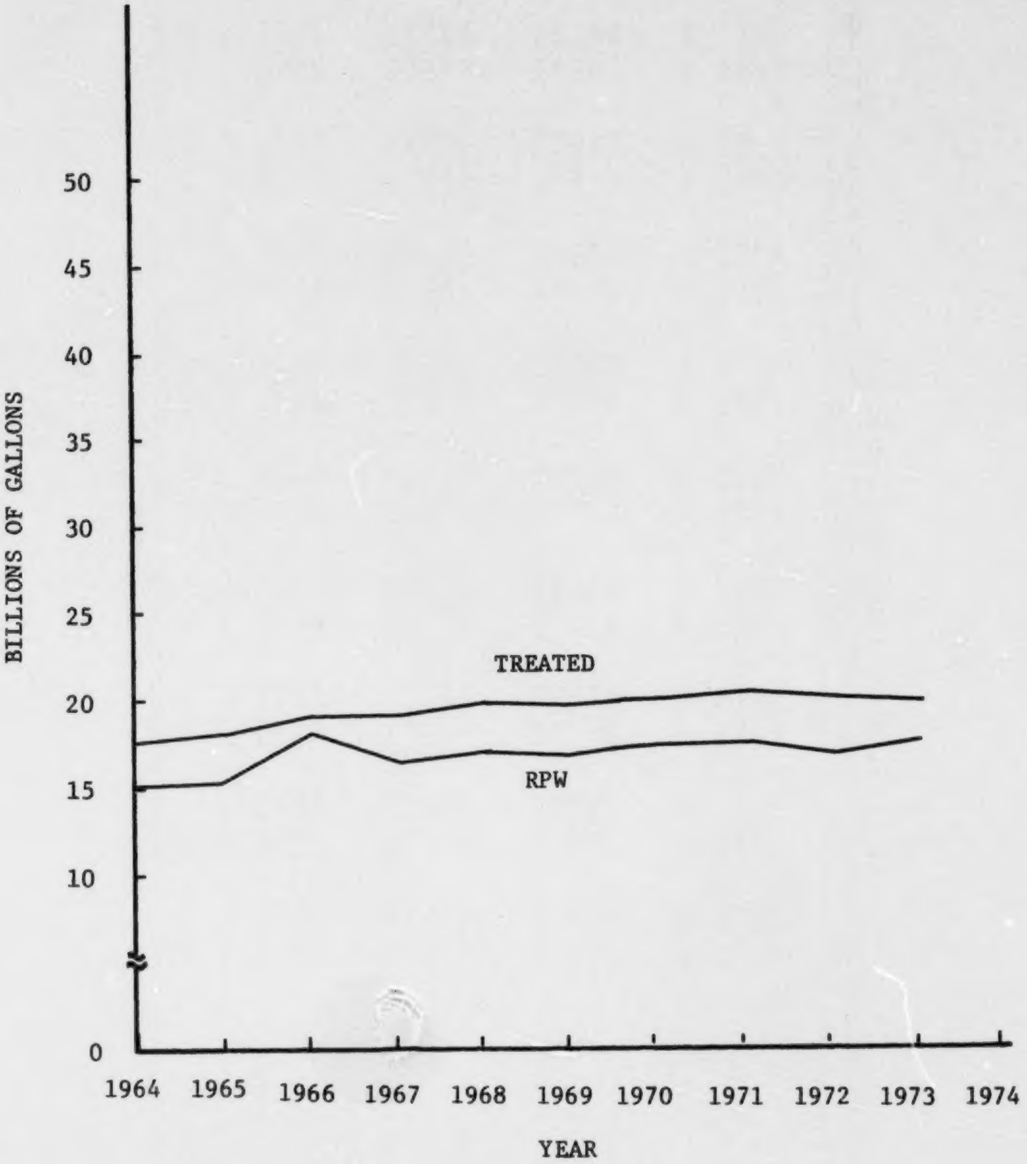


Figure 34. New Haven Water Company water flow: treated water versus RPW.

TABLE 63. NEW HAVEN WATER COMPANY ANNUAL OPERATING COSTS

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	$ 575,812	$ 594,472	$ 657,124	$ 696,339	$ 786,883	$ 917,121	$1,042,840	$1,100,552	$1,168,414	$1,260,410
Acctg and collection	392,675	419,961	469,759	513,362	535,449	537,291	666,485	769,117	869,258	988,000
Other	-	(34,420)	(48,946)	(59,001)	(40,482)	(38,946)	(62,607)	(49,529)	(51,462)	(72,466)
Total	968,487	980,013	1,077,937	1,150,700	1,281,850	1,415,466	1,646,718	1,820,140	1,986,210	2,175,944
Acquisition:	368,518	346,286	351,387	343,381	373,210	416,149	387,544	407,834	437,367	459,699
Treatment:										
Supervision and labor	111,280	118,409	143,153	156,026	155,632	163,319	174,225	179,325	174,600	197,683
Chemicals	33,461	30,180	35,110	55,976	62,426	56,147	71,729	72,687	78,532	64,218
Maintenance	10,434	11,108	8,556	17,276	19,633	21,800	17,248	21,149	12,073	15,610
Other	-	7,342	8,016	7,855	8,697	8,941	8,050	10,572	10,810	14,411
Total treatment	155,175	167,039	194,835	237,133	246,388	250,207	271,252	283,733	276,015	291,922
Power and pumping:										
Supervision and labor	59,446	59,668	87,630	53,303	27,127	30,876	34,504	35,169	22,358	31,221
Maintenance	14,894	9,996	15,860	20,782	26,695	27,759	29,022	28,559	29,903	32,283
Power	109,047	120,946	141,310	128,472	124,867	135,997	142,187	159,400	181,979	211,242
Other	6,997	6,112	6,912	5,593	4,887	6,799	8,987	8,293	8,836	8,133
Total power and pumping	190,384	196,722	251,712	208,150	183,576	201,431	214,700	231,421	243,076	282,879
Transmission and distribution:										
Operations	343,714	333,716	352,545	383,994	393,372	452,988	486,155	529,472	501,822	519,990
Maintenance	153,810	147,720	188,762	199,450	143,383	182,793	229,070	213,585	330,730	265,005
Other	81,115	82,579	98,856	114,667	129,132	138,306	137,790	145,734	144,043	144,320
Total transmission & distribution	578,639	564,015	640,163	698,111	665,887	774,087	853,015	888,791	976,595	929,315
Total operating cost	2,261,203	2,254,075	2,516,034	2,637,475	2,750,911	3,057,340	3,373,229	3,631,919	3,919,263	4,139,759
Capitalized as construction	530,026 *	457,833	543,793	588,097	575,989	621,020	831,120	876,952	1,047,973	1,125,019

* Estimated

TABLE 64. NEW HAVEN WATER COMPANY OPERATING COSTS/($/MIL GAL RPW)

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	$ 37.74	$ 38.14	$ 35.47	$ 42.21	$ 45.83	$ 53.56	$ 58.69	$ 61.38	$ 67.81	$ 71.15
Accounting and collection	25.74	26.94	25.36	31.12	31.19	31.38	37.51	42.89	50.45	55.78
Other	-	(2.21)	(2.64)	(3.58)	(2.36)	(2.27)	(3.52)	(2.76)	(2.99)	(4.09)
Total support services	63.48	62.87	58.19	69.75	74.66	82.67	92.68	101.51	115.27	122.84
Acquisition:	24.15	22.22	18.97	20.81	21.74	24.30	21.81	22.74	25.38	25.95
Treatment:										
Supervision and labor	7.29	7.60	7.73	9.46	9.07	9.54	9.80	10.00	10.13	11.16
Chemicals	2.19	1.94	1.90	3.39	3.64	3.28	4.04	4.05	4.56	3.63
Maintenance	0.68	0.71	0.46	1.05	1.14	1.27	0.97	1.18	0.70	0.88
Other	-	0.47	0.43	0.48	0.51	0.52	0.45	0.59	0.63	0.81
Total treatment	10.16	10.72	10.52	14.38	14.36	14.61	15.26	15.82	16.02	16.48
Power and pumping:										
Supervision and labor	3.90	3.83	4.73	3.23	1.58	1.80	1.94	1.96	1.30	1.76
Maintenance	0.98	0.64	0.86	1.26	1.55	1.62	1.63	1.59	1.74	1.82
Power	7.15	7.76	7.63	7.79	7.27	7.94	8.00	8.89	10.56	11.93
Other	0.46	0.39	0.37	0.34	0.28	0.40	0.51	0.46	0.51	0.46
Total power and pumping	12.49	12.62	13.59	12.62	10.69	11.76	12.08	12.90	14.11	15.97
Transmission and distribution:										
Operations	22.53	21.41	19.03	23.28	22.91	26.46	27.36	29.53	29.12	29.35
Maintenance	10.08	9.48	10.19	12.09	8.35	10.68	12.89	11.91	19.19	14.96
Other	5.32	5.30	5.34	6.95	7.52	8.08	7.75	8.13	8.36	8.15
Total transmission and distribution	37.93	36.19	34.56	42.32	38.78	45.22	48.00	49.57	56.67	52.46
Total operating cost	148.21	144.62	135.83	159.88	160.22	178.56	189.83	202.54	227.45	233.70
Capitalized as construction	34.74 *	29.38	29.35	35.65	33.55	36.27	4 .77	48.91	60.82	63.51

* Estimate

TABLE 65. NEW HAVEN WATER COMPANY OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	25.46	26.37	26.11	26.40	28.60	30.00	30.92	30.31	29.81	30.45
Acctg and collection	17.37	18.63	18.67	19.46	19.47	17.57	19.76	21.18	22.18	23.87
Other	-	(1.53)	(1.94)	(2.24)	(1.47)	(1.27)	(1.85)	(1.36)	(1.31)	(1.75)
Total support services	42.83	43.47	42.84	43.62	46.60	46.30	48.83	50.13	50.68	52.57
Acquisition:	16.29	15.36	13.97	13.02	13.57	13.61	11.49	11.23	11.16	11.10
Treatment:										
Supervision and labor	4.92	5.26	5.69	5.92	5.66	5.34	5.16	4.94	4.45	4.78
Chemicals	1.40	1.34	1.40	2.12	2.27	1.84	2.13	2.00	2.00	1.55
Maintenance	0.46	0.49	0.34	0.66	0.71	0.71	0.51	0.58	0.31	0.38
Other	-	0.32	0.32	0.30	0.32	0.29	0.24	0.29	0.28	0.35
Total	6.84	7.41	7.75	9.00	8.96	8.19	8.04	7.81	7.04	7.06
Power and pumping										
Supervision and labor	2.63	2.65	3.48	2.02	0.99	1.01	1.02	0.97	0.57	0.75
Maintenance	0.66	0.44	0.63	0.79	0.97	0.91	0.86	0.79	0.77	0.78
Power	4.82	5.37	5.62	4.87	4.54	4.45	4.21	4.39	4.64	5.10
Other	0.31	0.27	0.27	0.21	0.17	0.22	0.27	0.23	0.22	0.20
Total power and pumping	8.42	8.73	10.00	7.89	6.67	6.59	6.36	6.38	6.20	6.83
Transmission and distribution:										
Operations	15.20	14.80	14.01	14.56	14.30	14.82	14.41	14.58	12.80	12.56
Maintenance	6.80	6.56	7.50	7.56	5.21	5.98	6.79	5.88	8.44	6.40
Other	3.59	3.66	3.93	4.35	4.69	4.53	4.08	4.01	3.68	3.49
Total transmission & distribution	25.59	25.02	25.44	26.47	24.20	25.33	25.28	24.47	24.92	22.45
Capitalized as construction	23.44	20.31	24.12	22.30	26.48	20.65	24.64	31.83	26.74	27.18

TABLE 66. NEW HAVEN WATER COMPANY LABOR COST ANALYSIS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Total payroll * ($)	1,786,350	1,780,719	1,987,667	2,083,605	2,173,220	2,415,299	2,664,851	2,869,216	3,096,218	3,285,898
Total hours on payroll	---	---	---	---	---	715,520	690,560	713,440	686,400	682,240
RPW (mil gal)	15,256	15,585	18,526	16,498	17,168	17,122	17,769	17,931	17,231	17,714
Total payroll/mil gal RPW ($)	117.09	114.26	107.29	126.29	126.59	141.06	149.97	160.01	179.69	185.50
Total hours/mil gal RPW	---	---	---	---	---	41.79	38.86	39.79	39.84	38.51
Average cost/man-hour ($)	---	---	---	---	---	3.38	3.86	4.02	4.51	4.82
Payroll capitalized as construction ($)	N/A	322,163	378,405	423,806	392,573	397,271	558,420	557,629	712,524	771,979
Man-hours capitalized as construction	---	---	---	---	---	160,050	153,976	163,700	154,917	150,563

* Estimates as per 1973 distribution of salaries and wages (PUC pg. 313); to be revised during revisit.

TABLE 67. NEW HAVEN WATER COMPANY CAPITAL AND OPERATING COSTS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense	1,731,177	1,796,190	1,710,280	2,049,378	2,174,923	2,386,319	2,542,108	2,754,967	2,871,290	2,014,740
Depreciation	675,890	738,431	738,431	892,758	956,164	1,072,890	1,158,462	1,236,515	1,357,659	1,503,812
Other										
Interest	443,386	498,536	498,536	561,053	642,527	692,177	976,765	1,358,734	1,679,893	2,067,270
Taxes	2,207,766	2,161,481	2,161,481	2,467,516	2,647,209	3,068,840	3,449,890	4,016,819	3,782,864	3,741,714
Total	5,028,219	5,194,638	5,108,728	5,970,705	6,420,823	7,220,226	8,127,225	9,367,035	9,691,706	10,327,536
Total cost/mil gal RPW	329.59	333.31	275.76	361.90	374.00	421.69	457.38	522.39	562.46	583.02

TABLE 68. NEW HAVEN WATER COMPANY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense ($)	3,938,943	3,958,671	3,871,761	4,516,894	4,822,132	5,455,159	5,991,998	6,770,927	6,654,154	6,756,454
Taxes ($)	2,207,766	2,161,481	2,161,481	2,467,516	2,647,209	3,068,840	3,449,890	4,016,819	3,782,864	3,741,714
Capital expense ($)	1,119,276	1,236,967	1,236,967	1,453,811	1,072,890	1,598,691	1,765,067	2,135,227	2,595,249	3,037,552
Interest ($)	443,386	498,536	498,536	561,053	642,527	692,177	976,763	1,358,734	1,679,893	2,067,270
Total cost ($)	5,058,219	5,195,638	5,108,728	5,970,705	5,898,022	7,053,850	7,575,065	8,906,154	9,249,403	9,794,006
Operating expense as % of total	77.87	76.19	75.79	75.65	81.80	77.34	77.25	76.03	71.94	68.99
Capital expense as % of total	22.13	23.81	24.21	24.35	18.20	22.66	22.75	23.97	28.06	31.01

as a percent of the total shows that in the New Haven Water Company, more expenses are associated with operations than with capital.

Over the 10-year period, the trend has been in the direction of capital rather than operations and reflects the continual investment made by the New Haven Water Company in improving its system. The shift was from approximately 80% operating versus 20% capital in 1964 to 69% operating versus 31% capital in 1973.

The system is relatively old, and the capital depreciated was expended when costs were significantly lower than at present. On the other hand, the operating expense is in current dollars. This ratio will significantly increase as major capital investments are made by the utility. For example, the company is starting to make major capital expenditures for treatment facilities. As these expenditures are made, the ratio of capital to operating expenses will increase significantly.

From a cost standpoint, New Haven Water Company is unusual in that the utility made major investments in large areas of land to control source water. Because of this, the company incurred liability for real estate taxes. Table 67 shows that a total of $3.7 million was paid for taxes in 1973. Most of this was real estate tax. This value divided by the billed consumption (17,714 mil gal) for 1973 shows that $211.23 was paid in taxes for each mil gal of water sold to consumers.

SYSTEM COSTS

Explanation of costs on a functional basis is only part of the total picture. Because the purpose of the utility is to deliver water to a consumer, it is important to present costs as they relate to the delivery of water to a demand point within the system. This section contains such an analysis.

Locations of the company's facilities are shown in Figure 35. To analyze the cost of water as it moves through acquisition to treatment to the customer, it is necessary to identify the capital and operating cost of each system component. Figure 36 is a schematic diagram of Figure 35 and shows the operating and capital costs for each of the system's major facilities. A linear assumption is made to allow unit cost/($/mil gal) to be added as water moves from one system component to another. Transmission distances are relatively short because water is added at many points within the system. Little variation exists in the cost of providing water to any specific point in the service area.

The terrain served is relatively level, reservoirs are generally located on higher ground, and the water is gravity fed into the distribution system. The exception to this occurs in the well fields and the Lake Whitney reservoir, where the water is lifted into the system. Once the water is in the distribution system, it is pumped to maintain pressure and to lift the water into the standpipes. Generally speaking, because the water enters the distribution system and is pumped at so many various points, it is normally

A	Cheshire Wells
AA	First Avenue Pump
C	Sleeping Giant Wells
CC	Rabbit Rock Pump
D	High Rock Pump
DD	North Branford Pump and Treatment
H	Mount Carmel Wells
HH	Saltonstall Pump and Filters
I	Dawson Pump
II	Cherry Hill Pump
J	Dawson Treatment
L	Wintergreen Pump and Treatment
P	Whitney Pump and Filters
R	Maltby Pump and Treatment
T	Spring Street Pump
Y	Beaver Brook Pump

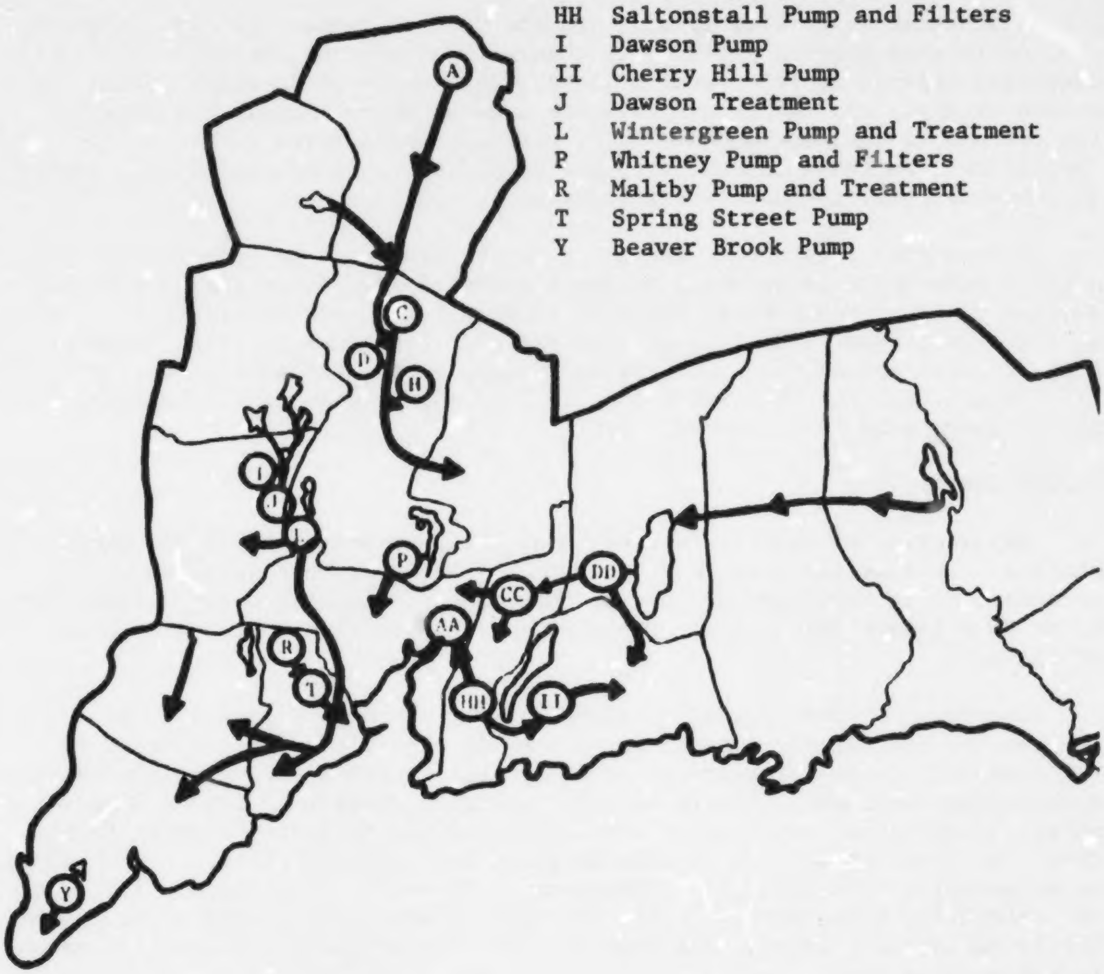


Figure 35. New Haven Water Company location of facilities and general direction of water flow in the retail service areas.

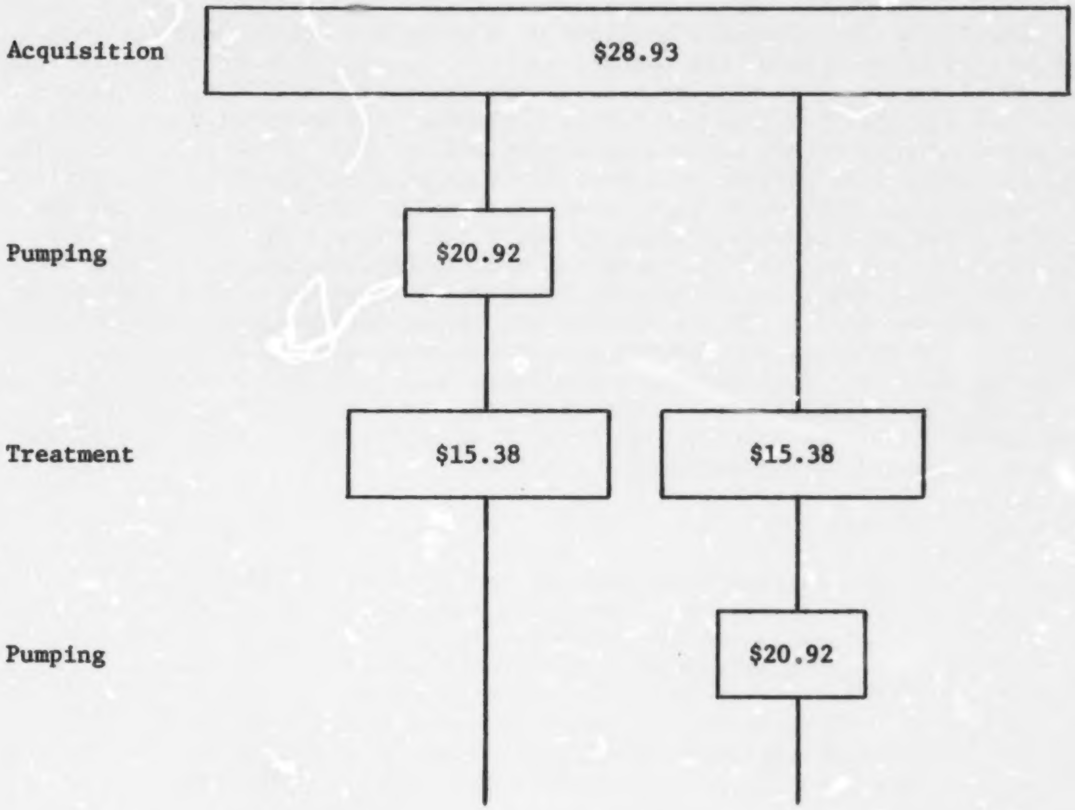

Acquisition
$28.93
Pumping
$20.92
Treatment
$15.38
$15.38
Pumping
$20.92

Figure 36. New Haven Water Company allocation of capital and operating expenses to water system components ($/mil gal RPW).

delivered to the consumer without being repumped. Since the cost for repumping is small, it is included in the cost of the initial pumping.

Figure 36 shows the costs associated with acquiring, treating, and pumping water within the system. As discussed, water is not transported over great distances, and the schematic presentation is simple. The only significant variation in the system is whether the pumping occurs before or after the chlorine and fluoride are added. This does not affect the cost.

Available data allowed a breakout of capital and operating costs only to the general categories of the operations. For example, breakout cost on each individual reservoir or well system was not available, and it was necessary to accumulate all the costs related to the reservoirs and divide the total by the RPW to arrive at the total acquisition cost of $28.93/mil gal. Using the same procedure, the pumping cost is $20.92/mil gal, and the treatment cost is $15.38/mil gal. The sum of these costs is $65.23, which represents the incremental cost for providing water to any distribution point in the system. Added to this expense are the costs for distribution, interest, and support services. Distribution cost is calculated on the assumption that the cost/mil gal is constant throughout the system; therefore, total capital and operating costs for distribution are divided by the number of gallons of revenue-producing water for the year under consideration. The same approach is taken for taxes ($211.23/mil gal), as described earlier. Adding the cumulative sums gives an average cost for delivery of water to the consumer of $583.01/mil gal. These data are outlined as follows:

Costs:

Incremental	$65.23
Distribution	86.45
Interest	116.70
Support services	103.40
Taxes	211.23
Total	583.01
Metered consumption (mil gal)	17,714
Revenue ($)	10,327,439

Once these calculations are made, costs versus charges can be examined. Tables 69 through 73 summarize charges for typical monthly water consumption in New Haven. Table 74 gives RPW for the 10 largest customers of the New Haven Water Company.

Converting the units used to mil gal and dividing that into the amount billed makes it possible to examine the amount actually paid/mil gal, as shown in the last column of Table 73.

Because water is delivered to all users within the service area at approximately the same cost, it is possible to compare the average cost of delivering water with the amount paid by the major users. This comparison shows that major users are not paying the cost of producing and delivering water.

TABLE 69. NEW HAVEN WATER COMPANY QUARTERLY RATE SCHEDULE*

Units used (cu ft)	Cost/100 cu ft
First 500 or less+	---
Next 29,500	$0.63
Next 70,000	.49
Next 900,000	.37
Over 1,000,000	

* For all meter sizes.
+ See Table 70.

TABLE 70. NEW HAVEN WATER COMPANY QUARTERLY RATE SCHEDULE

Meter size (in.)	Charge for 1st 500 cu ft or less	Minimum charge	Allowance for minimum charge (cu ft)
5/8 + 3/4	$10.38	$12.38	500
1	12.46	17.50	1,300
1½	16.61	29.21	2,500
2	20.66	42.71	4,000
3	33.03	77.13	7,500
4	49.49	125.09	12,500
6	90.59	244.94	25,000
8	131.25	378.35	42,500
10	172.68	517.78	62,500
Privately owned	3.15	3.15	500

TABLE 71. NEW HAVEN WATER COMPANY SEASON RATE SCHEDULE*

Units used (cu ft)	Cost/100 cu ft
First 1,300 or less+	---
Next 68,700	$0.63
Next 163,300	.49
Over 233,500	.37

* For all meter sizes.
+ See Table 72.

TABLE 72. NEW HAVEN WATER COMPANY SEASON RATE SCHEDULE

Meter size (in.)	Charge for 1st 1,300 cu ft or less	Minimum charge	Allowance for minimum charge (cu ft)
5/8 + 3/4	$46.53	$46.53	1,300
1	51.73	63.70	3,200
1½	62.11	93.61	6,300
2	72.23	127.04	10,000
3	103.16	213.41	18,800
4	144.31	333.31	31,300

TABLE 73. NEW HAVEN WATER COMPANY QUARTERLY RATE CHARGE ANALYSIS

Units used (cu ft)	Gallons used	Meter size (in.)	Charge
13.4	10,000	5/8	$15.67
5,000	3,740,260	4	2,058.34
100,000	74,805,200	10	29,681.53
150,000	112,207,800	10	43,931.53

TABLE 74. RPW FOR NEW HAVEN WATER COMPANY'S TEN MAJOR USERS

Major user	High or low month	Month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Cost zone
Olin Corporation	High	Oct	120.0	$32,105.90	$267.62	1
	Low	Mar	80.6	21,724.14	269.63	
Yale University	High	*	296.5	101,036.89	340.72	1
	Low		249.6	88,694.19	355.29	
Simkins Industry	High	Sep	42.6	11,684.34	274.40	1
	Low	Jul	24.3	6,850.07	282.34	
United Illinois Co.	High	Sep	31.3	8,697.56	278.21	1
	Low	Mar	17.8	5,163.13	289.85	
Armstrong	High	Apr	30.1	8,429.12	279.98	1
	Low	May	17.8	5,182.43	290.82	
Federal Paper	High	Feb	22.8	6,479.14	284.42	1
	Low	Mar	10.7	4,226.16	396.32	
Schick	High	Sep	22.9	6,490.16	283.44	1
	Low	Mar	11.3	3,446.57	304.79	
Connecticut Light and Power	High	Apr	23.8	7,196.78	301.94	1
	Low	Mar	12.1	4,116.20	340.35	
Upjohn	High	Feb	20.1	6,238.03	309.89	1
	Low	Mar	12.8	4,313.99	335.98	
Penn Central	High	Jan	11.8	3,668.15	309.94	1
	Low	Nov	6.5	2,242.10	342.83	

* Billed quarterly.

The average costs/mil gal for all water supplied during the most recent year studied are given as follows:

	$/mil gal
Support services	$113
Acquisition	29
Treatment	15
Distribution	107
Interest	117
Taxes	179
Total	560

SECTION 10

FAIRFAX COUNTY WATER AUTHORITY

The Fairfax County Water Authority, headquartered in Annandale, Virginia, was created under the Virginia Water and Sewage Authority Act of 1950 and chartered by the State Corporation Commission on September 26, 1957, for the purpose of acquiring, constructing, operating, and maintaining an integrated water system to supply and distribute water to Fairfax County. The charter was amended in 1959 to add the provision for sewer systems and sewage disposal systems located within Fairfax County and partly within and without the county.

The Authority is a public body politic incorporate deemed to be an instrumentality exercising public and essential governmental functions to provide for the public health and welfare. The Authority is empowered to: (1) acquire, construct, operate, and maintain water supply systems; (2) finance its programs through the issuance of revenue bonds without obtaining referendum approval; and (3) fix and prescribe rates, fees, and charges for the service rendered. It cannot levy any taxes or assessments, nor do the obligations of the Authority become obligations of Fairfax County.

Since 1959, the Authority has acquired 15 water companies, consisting of 22 separate water systems. The Alexandria Water Company, acquired in 1967, served 70% of the customers gained through the acquisition of 15 companies.

The Fairfax County Water Authority serves approximately two-thirds of the population (364,000) in Fairfax County and small areas in adjoining counties. The population is relatively stable, and little construction activity is taking place in the service area. System facts are given in Table 75.

WATER SUPPLY SERVICE AREA

The retail service area shown in Figure 37 encompasses approximately 400 sq miles in Fairfax County. Water is supplied to some areas lying partly outside the county, such as Dulles Airport. In addition to serving county residents, the Authority wholesales treated water to places such as Alexandria, Prince William Water Company, and other areas located in or near Fairfax County.

The service area is relatively level, with elevations varying between 0 to 510 ft above sea level. The treatment plant is located at 260 ft above sea level, or approximately in the middle of the elevation range.

TABLE 75. FAIRFAX COUNTY WATER AUTHORITY, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	
County	552,000
Retail service area	364,000
Area of retail service area (sq miles)	400
Recognized customer classes (no. of metered accounts):	
Single family	71,977
Townhouses	8,650
Apartments	1,188
Commercial and industrial	2,635
Municipal-institutional	515
Flat Rate (no. of accounts)	None
Percent metered	100
Purchased water (mil gal treated)	1,627
Source water	97% Surface, 3% Wells
Pipe in system (miles)	1,256
Elevation of treatment plant (ft above mean sea level)	260
Elevation of service area (min-max ft)	0 - 510
Revenue-producing water (mil gal)	21,411
Treated water (pumpage from treatment plants + treated purchased water, mil gal)	19,096
Maximum day/maximum hour (MGD)	91/N.A.

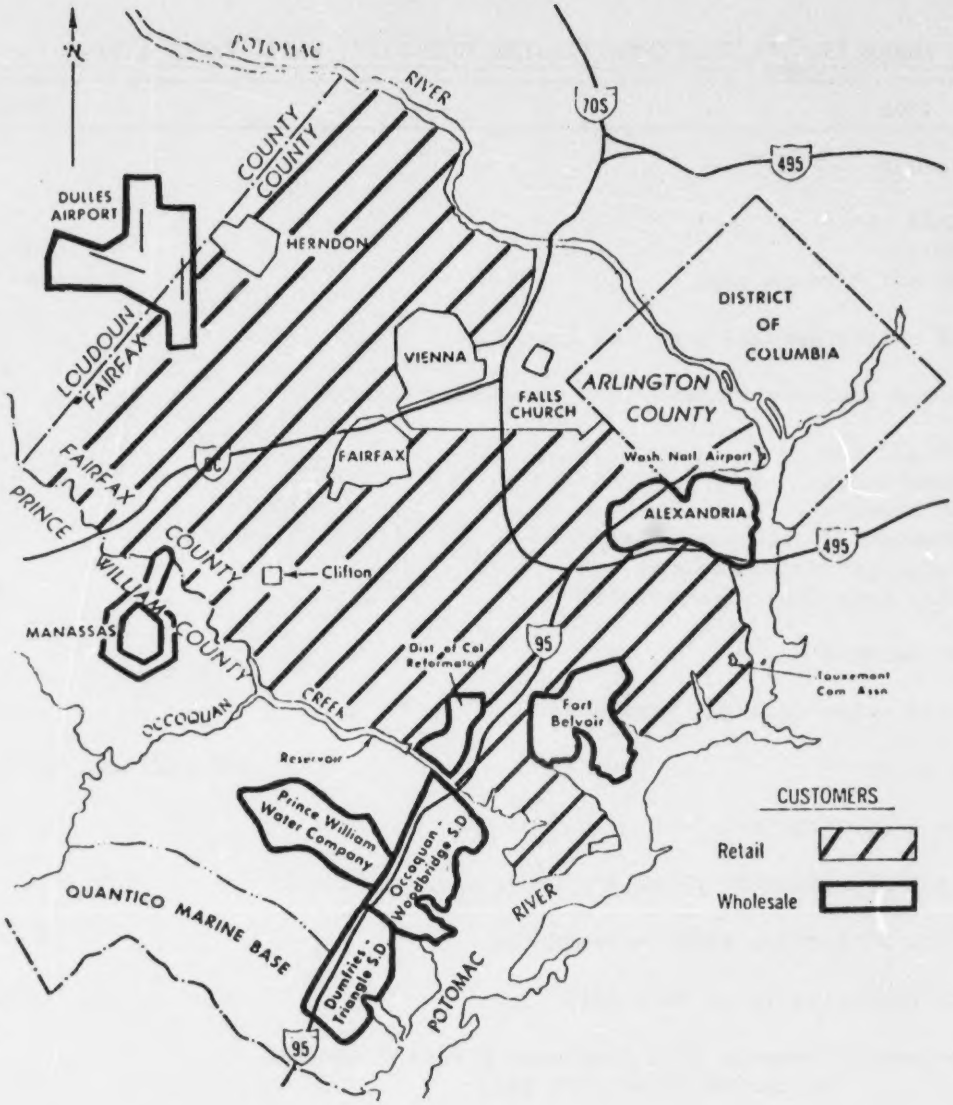

N
POTOMAC RIVER
70S
495
DULLES AIRPORT
HERNDON
LOUDOUN COUNTY
FAIRFAX COUNTY
DISTRICT OF COLUMBIA
VIENNA
FALLS CHURCH
ARLINGTON COUNTY
66
FAIRFAX
Wash. Nat'l Airport
ALEXANDRIA
495
FAIRFAX COUNTY
PRINCE WILLIAM COUNTY
Clifton
MANASSAS
95
Dist of Col Reformatory
Fort Belvoir
Tauxemont Com Assn
OCCOQUAN CREEK
Reservoir
Prince William Water Company
Occoquan - Woodbridge S.D.
Dumfries - Triangle S.D.
QUANTICO MARINE BASE
POTOMAC RIVER
95
CUSTOMERS
Retail
Wholesale

Figure 37. Fairfax County Water Authority location map and service areas.

This area is not expected to expand significantly in size unless an additional water system (such as the City of Fairfax) is acquired; however, the population is projected to increase the water demands at a rate of 3% to 4%/year through the year 1985.

ORGANIZATION

The Authority is administered by a board of five members appointed by the County Board of Supervisors for staggered terms of 3 years each. Officers are elected by the members for a term of 1 year. Operations are accomplished by a director who reports to the five-member board.

As shown in Figure 38, the director has four divisions reporting to him: (1) Engineering and Construction, responsible for designing and building facilities; (2) Finance, principally responsible for acquiring funds to support the operations; (3) Operations and Maintenance, responsible for accomplishing the production work and maintaining the equipment; and (4) General Services, responsible for performing the support activities necessary to the operation of the utility.

Although the charter includes the right to provide sewage service, none is provided at present time and therefore it was not necessary to separate costs for water and sewage functions.

ACQUISITION

Raw water for the Fairfax County Water Authority comes from both surface and ground sources. Approximately 97% of the water used is surface water, and 3% is groundwater.

The principal source of water is the Occoquan River, located in Fairfax, Fauquier, Loudon, and Prince William Counties with an impounded watershed of approximately 570 sq miles. Two dams constructed near Occoquan impound the river for water supply. The lower dam, constructed in 1950, impounds a relatively small reservoir containing about 55 mil gal, and the upper dam, constructed approximately 3,000 ft upstream from the lower dam in 1957, impounds a reservoir containing about 9.8 billion gallons. As presently developed, the impounding water supply has a dependable yield of approximately 65 MGD, even under the most severe drought conditions of record. Usually during the months of November through April, hydroelectric generating facilities utilize surplus stream flow to generate the power for pumping and treating water.

Supplementary sources of water include 30 wells and the purchase of water from Fort Belvoir and the cities of Fairfax and Falls Church. Provisions in the design and construction of the larger dam will permit 5-ft increase in height, which will increase storage by about 3 billion gallons. This additional storage will increase the dependable yield to approximately 84 MGD. Easements have been obtained for flooding the additional acerage along the shoreline when the height of the dam is increased.

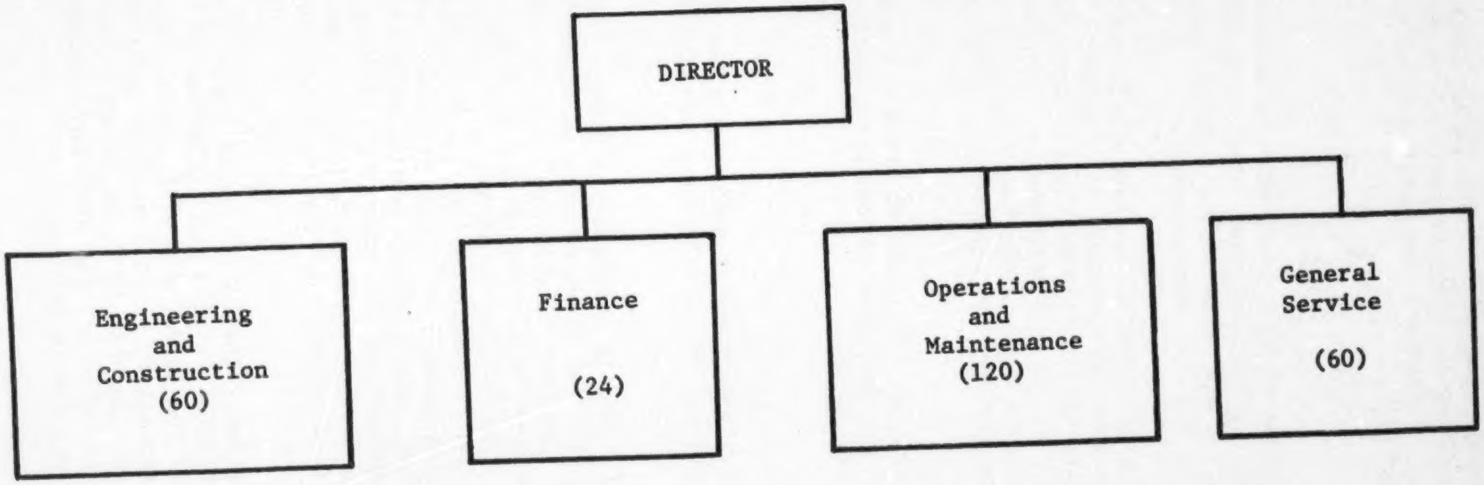

DIRECTOR
Engineering and Construction (60)
Finance (24)
Operations and Maintenance (120)
General Service (60)

Figure 38. Fairfax County Water Authority organizational chart.

TREATMENT

Water treatment is provided in two interconnecting plants constructed in stages during the period 1950 to 1973. The combined maximum capicity of these facilities is 99.6 MGD.

The principal chemicals used in the treatment process include: (1) chlorine for disinfection, manganese and iron removal as well as taste and odor control, (2) activated carbon for taste and odor control, (3) alum to assist in the coagulation and settling of suspended materials, (4) lime to increase alkalinity for optimum coagulation and to inhibit pipe corrosion, (5) potassium permanganate for magnesium removal, (6) sodium bisulfite as a dechlorinating agent, and (7) fluoride for retardation of tooth decay. Four filtered water reservoirs containing about 4.8 mil gal are located at the treatment plant. Figure 39 presents a schematic diagram of the treatment plant.

TRANSMISSION AND DISTRIBUTION

The transmission and distribution system of the Fairfax County Water Authority consists of approximately 1,256 miles of mains varying in diameter from 2 to 30 in. Water is delivered into the transmission and distribution system by 18 pumping units providing a maximum capacity of 100 MGD. Operating pressures are maintained throughout the service area by 22 booster pumping stations, with capacities ranging from 0.13 to 41.0 MGD.

A total of 19 mil gal water is stored in 44 reservoirs located within the service area principally, as follows: 9 mil gal in three standpipes near Annandale, 5 mil gal in two standpipes at Gum Springs, 2 mil gal in two standpipes at Penderwood, and 1 mil gal in an elevated storage tank at the Fairfax County Hospital.

The distribution system is interconnected at 62 locations with 12 other water systems in northern Virginia. Five of these systems have independent water supply sources, and seven are dependent on the Authority for their water supply. The water storage facilities of the Fairfax County Water Authority, their number, and capacity are listed in Table 76.

In addition to its principal system, the Authority owns and operates seven independent well systems providing service to about 300 customers in communities distant from the principal system.

COST ANALYSIS

The rapid growth in RPW from 1964 through 1973 (Figure 40) reflects the acquisition of utilities rather than new customers within the service area. The acquisition of the Fairfax Water Company in 1967 more than doubled the amount of water sold by the Authority.

Using the standard cost categories, data were collected and reported as shown in Tables 77, 78, and 79. There are no data breakouts below the level of the total before 1968; the operations changed so radically in 1967 with

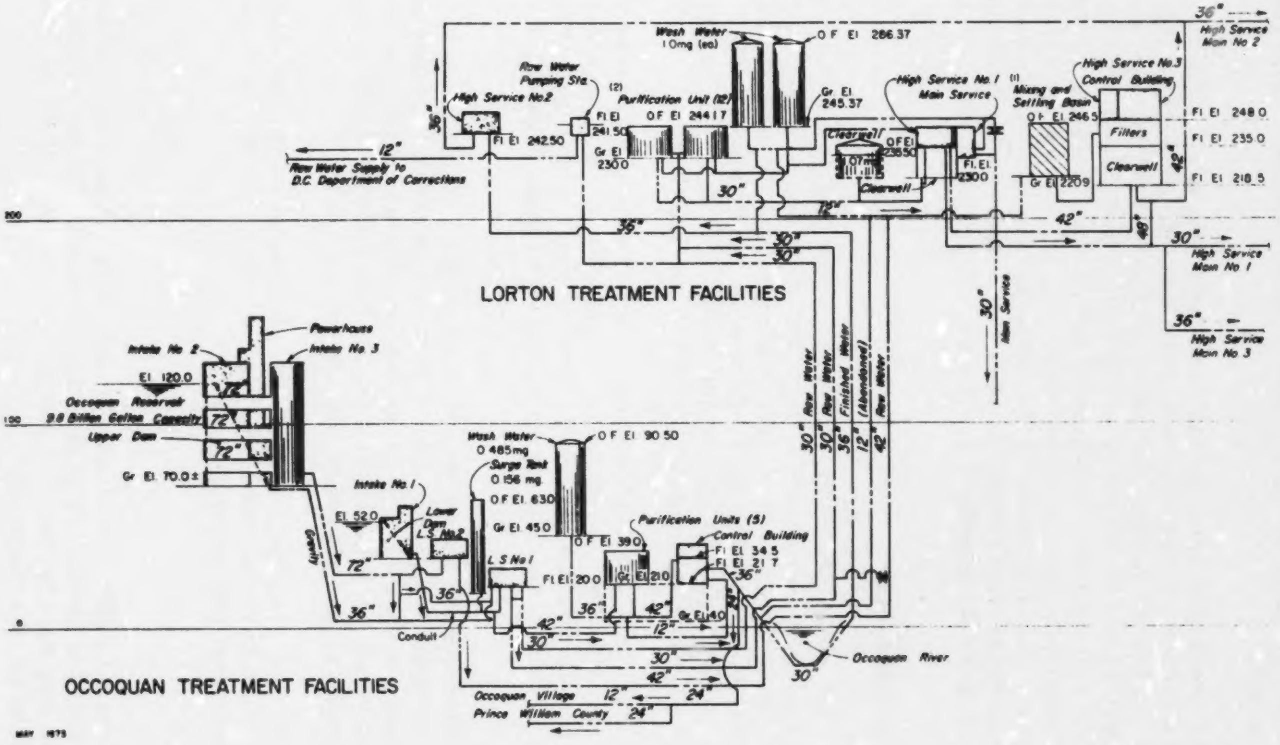

LORTON TREATMENT FACILITIES
OCCOQUAN TREATMENT FACILITIES
200
100
0
High Service No.2
Fl El 242.50
Raw Water Pumping Sta.
(2)
Fl El 241.50
Gr El 230.0
Purification Unit (12)
O F El 244.17
Wash Water 1.0mg (ea)
O F El 286.37
Gr. El 245.37
Clearwell
O F El 235.50
1.07mg
Clearwell
High Service No. 1 Main Service
Fl. El. 230.0
(1)
Mixing and Settling Basin
O F El 246.5
Gr El 220.9
High Service No.3 Control Building
Filters
Clearwell
Fl El 248.0
Fl El 235.0
Fl El 218.5
High Service Main No 2
High Service Main No 1
High Service Main No 3
Main Service
Raw Water Supply to D.C. Department of Corrections
12"
36"
30"
42"
48"
Raw Water
Finished Water
(Abandoned)
Powerhouse
Intake No 2
Intake No. 3
El 120.0
Occoquan Reservoir 9.8 Billion Gallon Capacity
Upper Dam
Gr El. 70.0±
72"
Intake No. 1
El. 52.0
Lower Dam
L.S. No.2
Gravity
L.S. No 1
Conduit
Wash Water 0.485mg
Surge Tank 0.156 mg.
O F El. 63.0
Gr El. 45.0
O F El 90.50
O F El 39.0
Fl El 20.0
Gr El 21.0
Purification Units (5)
Control Building
Fl El 34.5
Fl El 21.7
Gr El 4.0
Occoquan River
Occoquan Village
Prince William County
24"
MAY 1973

Figure 39. Fairfax County Water Authority schematic diagram of treatment facilities.

TABLE 76. FAIRFAX COUNTY WATER AUTHORITY STORAGE FACILITIES

Facility	Standpipes Number	Standpipes Total capacity (mil gal)
Annandale	3	9
Gum Springs	2	5
Penderwood	2	2
Fairfax County Hospital (elevated tank)	1	1
40 Locations (miscellaneous storage)	---	2
Total storage capacity		19

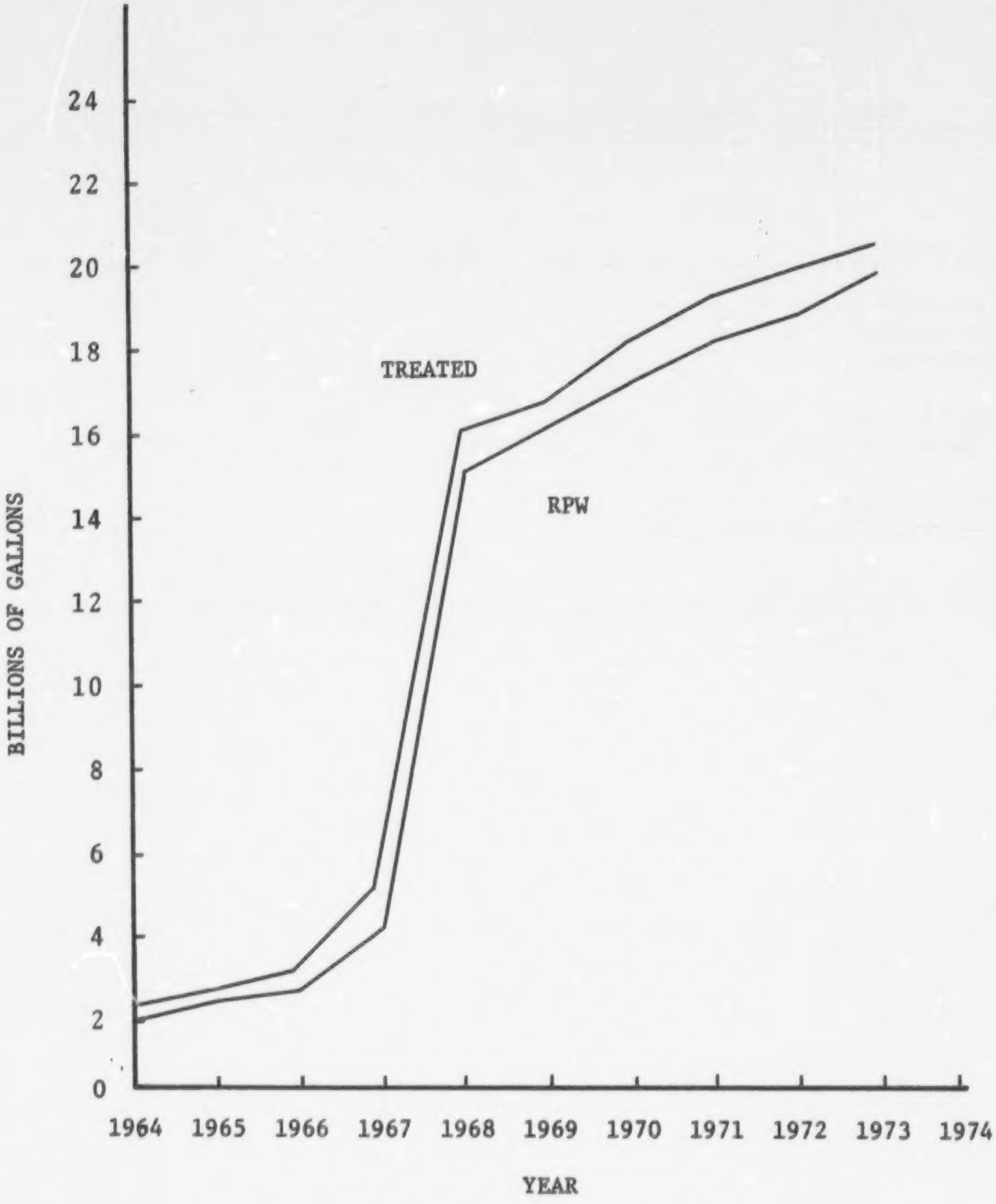


Figure 40. Fairfax County Water Authority water flow: treated water versus RPW.

TABLE 77. FAIRFAX COUNTY WATER AUTHORITY ANNUAL OPERATING COSTS*

Category	1964+	1965	1966	1967	1968	1969	1970	1971	1972	1973‡
Support services:										
Administration	---	---	---	---	$ 108,576	$ 79,520	$ 91,124	$ 115,267	$ 120,524	$ 163,791
Accounting and collection	---	---	---	---	256,520	341,445	392,215	471,967	491,998	719,886
Other	---	---	---	---	308,194	579,233	769,956	645,210	793,847	665,136
Total support services	---	---	---	---	673,290	1,000,198	1,253,295	1,232,444	1,406,369	1,548,813
Acquisition:										
Personnel	---	---	---	---	16,928	23,410	21,188	25,525	24,633	---
Water purchased	---	---	---	---	128,490	179,948	226,970	259,171	215,705	341,832
Maintenance	---	---	---	---	4,543	2,378	1,588	4,178	3,010	---
Other	---	---	---	---	277	33	1	78	---	---
Total acquisition	---	---	---	---	150,238	205,769	249,747	288,952	243,348	387,470
Treatment:										
Personnel	---	---	---	---	168,224	179,716	223,696	256,252	279,924	---
Chemicals	---	---	---	---	249,153	350,688	312,576	259,208	269,633	325,340
Other	---	---	---	---	44,434	33,660	38,210	39,105	36,460	---
Total treatment	---	---	---	---	461,811	564,064	574,482	554,565	586,017	584,170
Power and pumping:										
Personnel	---	---	---	---	84,738	112,739	108,212	149,526	185,058	---
Power	---	---	---	---	225,284	248,880	279,512	286,918	309,795	350,195
Maintenance	---	---	---	---	14,180	17,925	15,776	15,979	21,000	---
Other	---	---	---	---	5,642	4,364	5,099	10,153	12,125	---
Total pumping	---	---	---	---	329,844	383,908	408,599	462,576	527,978	526,275
Transmission and distribution:										
Personnel	---	---	---	---	199,573	225,555	259,511	307,050	408,495	---
Maintenance	---	---	---	---	68,809	48,605	97,042	123,908	107,112	---
Other	---	---	---	---	433,567	462,760	386,347	486,943	658,382	---
Total trans. and distribution	---	---	---	---	701,949	736,920	742,900	917,901	1,173,989	1,385,546
Total operating cost	$707,901	$834,487	$1,096,406	$1,345,317	2,317,132	2,890,859	3,229,023	3,456,438	3,937,701	4,432,274

* As per total current expenses from respective annual reports.

+ Except for totals, 1964-67 data are excluded because they are not comparable to 1968-73 data, the period after acquisition of the Alexandria Waterworks.

‡ Cost figures for certain categories not complete.

TABLE 78. FAIRFAX COUNTY WATER AUTHORITY UNIT OPERATING COSTS ($/mil gal RPW)

Category	1964*	1965	1966	1967	1968	1969	1970	1971	1972	1973
Support services:										
Administration	---	---	---	---	$ 7.30	$ 4.96	$ 5.34	$ 6.55	$ 6.51	$ 8.52
Accounting and collection	---	---	---	---	17.26	21.31	23.01	26.82	26.59	37.43
Other	---	---	---	---	20.73	36.16	45.16	36.66	42.90	34.58
Total support services	---	---	---	---	45.29	62.43	73.51	70.03	76.00	80.53
Acquisition:										
Personnel	---	---	---	---	1.14	1.46	1.24	1.45	1.33	---+
Water purchased	---	---	---	---	8.64	11.23	13.31	14.73	11.66	17.77
Maintenance	---	---	---	---	.31	.15	.09	.24	.16	---
Other	---	---	---	---	.02	---	---	---	---	---
Total acquisition	---	---	---	---	10.11	12.84	14.64	16.42	13.15	20.15
Treatment										
Personnel	---	---	---	---	11.32	11.22	13.12	14.56	15.13	---
Chemicals	---	---	----	---	16.67	21.89	18.33	14.73	14.57	16.92
Other	---	---	---	---	2.99	2.10	2.24	2.22	1.97	---
Total treatment	---	---	---	---	31.07	35.21	33.69	31.51	31.67	30.37
Power and pumping										
Personnel	---	---	---	---	5.70	7.04	6.35	8.50	10.00	---
Power	---	---	---	---	15.15	15.54	16.39	16.30	16.74	18.21
Maintenance	---	---	---	---	.95	1.12	.93	.91	1.13	---
Other	---	---	---	---	.38	.27	.30	.58	.66	---
Total power and pumping	---	---	---	---	22.18	23.97	23.97	26.29	28.53	27.36
Transmission and distribution:										
Personnel	---	---	---	---	13.42	14.08	15.22	17.45	22.08	---
Maintenance	---	---	---	---	4.63	3.03	5.69	7.04	5.79	---
Other	---	---	---	---	29.17	28.89	22.66	27.67	35.58	---
Total Transmission and distribution	---	---	---	---	47.22	46.00	43.57	52.16	63.45	72.05
Total unit operating cost	$397.92	$402.22	$451.57	$340.59	155.87	180.45	189.38	196.41	212.80	230.46

* Except for totals, 1964-67 data are excluded because they are not comparable to 1968-73 data, the period after acquisition of the Alexandria Waterworks.

+ Insufficient information.

TABLE 79. FAIRFAX COUNTY WATER AUTHORITY OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	* 1968	1969	1970	1971	1972	1973
Support Services:						
Administration	4.68	2.75	2.82	3.33	3.06	3.70
Accounting and collection	11.07	11.81	12.15	13.66	12.50	16.24
Other	13.31	20.04	23.85	18.67	20.15	15.00
Total support services	29.06	34.60	38.82	35.66	35.71	34.94
Acquisition:						
Personnel	0.73	0.81	0.65	0.74	0.63	---+
Water purchased	5.54	6.22	7.03	7.50	5.48	7.71
Maintenance	0.20	0.08	0.05	0.12	0.08	---
Other	0.01	---	---	---	---	---
Total acquisition	6.48	7.11	7.73	8.36	6.19	8.74
Treatment:						
Personnel	7.26	6.22	6.93	7.41	7.11	---
Chemicals	10.75	12.13	9.68	7.50	6.85	7.34
Other	1.92	1.16	1.18	1.13	0.93	---
Total treatment	19.93	19.51	17.79	16.04	14.89	13.18
Power and pumping:						
Personnel	3.66	3.90	3.35	4.33	4.70	---
Power	9.72	8.61	8.65	8.30	7.87	7.90
Maintenance	0.61	0.62	0.49	0.46	0.53	---
Other	0.24	0.15	0.16	0.30	0.31	---
Total power and pumping	14.23	13.28	12.65	13.39	13.41	11.87
Transmission and distribution:						
Personnel	8.61	7.80	8.04	8.88	10.38	---
Maintenance	2.97	1.68	3.00	3.58	2.71	---
Other	18.72	16.01	11.97	14.09	16.71	---
Total transmission and distribution	30.30	25.49	23.01	26.55	29.80	31.27
Total operating expense	100.00	100.00	100.00	100.00	100.00	100.00

* Excludes 1964-67 data because they are not comparable to 1968-73 data, the period after acquisition of the Alexandria Waterworks.

+ Insufficient information.

the acquisition of the Alexandria Waterworks that any breakout on a comparative basis is not meaningful. Even the 1968 data are somewhat questionable, because the Authority was still suffering the impact of the major change.

The effect of selling more water is readily seen in Table 78. During the preceding years, the unit operating cost was in the neighborhood of $400/mil gal. In 1968, with the larger amount of water sold, the operating cost decreased sharply to $155/mil gal. From that point on, a steady and rather consistent increase on a $/mil gal basis has occurred each year.

The relative increase in cost for support services is significantly higher than for other areas of the operating budget. Table 80 examines labor costs associated with the operation and maintenance activities of the utility. The cost/man-hour from 1968 through 1973 increased by 54%, and the total payroll hours required to produce 1 mil gal of RPW increased by 14 percent. Because more man-hours are required and because the cost/man-hour is increasing, total cost for support services is compounding.

Operating and capital costs are summarized in Table 81 for the full 10-year period. As indicated by the capital and interest figures, a major change occurred between 1967 and 1968, when the major capital investment was made.

Capital and operating expense ratios are computed in Table 82. The operating expenses shown are the costs incurred in the normal day-to-day operation of the system. The capital expenses are the total expenses for providing major equipment items and facilities plus the interest charged on money borrowed for that purpose.

A comparison of the operating and capital expenses as a percent of the total cost shows that in the Fairfax County Water Authority, more expenses are associated with capital than with operations. This is contrary to the condition found in most of the utilities monitored and is surely influenced by the fact that the major capital expenditure of Fairfax County is more recent than in most of the systems. Again, a significant shift can be seen between 1967 and 1968, when the ratio of operating to capital expense decreased from 46 percent to 27 percent. The ratio is gradually shifting more toward the operating area; by 1973 it reached 44% because of rapid increases in operating costs, especially in the labor area.

SYSTEM COSTS

Examination of cost on a functional basis is only a part of the total cost picture. Since the purpose of the water supply utility is to deliver water to its customers, it is important to present costs in such a way that they relate the delivery of water to a demand point within the distribution system. The functional categories, both operating and capital, will therefore be reaggregated and assigned to physical components of the water system. This section contains such an analysis of the water supply system's cost.

TABLE 80. FAIRFAX COUNTY WATER AUTHORITY LABOR COST ANALYSIS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Total payroll ($)	338,111	447,765	541,529	708,289	1,191,623	1,401,918	1,623,016	2,039,253	2,405,568	2,696,576
Total hours on payroll	---	---	---	---	352,605	374,217	352,712	449,566	492,488	519,994
Revenue-producing water (mil gal)	1,779	2,199	2,428	3,950	14,866	16,020	17,049	17.699	18,504	19,232
Total payroll/mil gal RPW ($)	190.06	203.62	223.04	179.31	80.16	87.51	95.21	115.22	130.00	140.21
Total hours/mil gal RPW	---	---	---	---	23.72	23.36	20.69	25.40	26.69	27.04
Average cost/man hour ($)	---	---	---	---	3.38	3.75	4.60	4.54	4.88	5.19

TABLE 81. FAIRFAX COUNTY WATER AUTHORITY CAPITAL AND OPERATING COSTS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating cost	$707,901	$884,487	$1,096,406	$1,345,317	$2,317,132	$2,890,859	$3,229,023	$3,456,438	$3,937,701	$4,432,271
Depreciation	234,464	234,464	240,982	912,326	1,583,865	1,583,865	1,583,865	1,583,865	1,583,865	1,586,914
Interest*	608,006	663,038	663,038	663,038	4,799,993	3,401,288	4,934,620	4,105,420	4,059,620	4,011,220
Total cost	1,550,371	1,781,989	2,000,426	2,920,681	8,700,990	7,876,012	9,747,508	9,145,723	9,581,186	10,030,405
Total unit cost ($/mil gal)	871.48	810.36	823.90	739.41	585.29	491.64	571.73	516.74	517.79	521.55

* Interest figures for 1964, 1965, 1966, 1967, and 1969 were taken from the Annual Report. Other years were taken from the Interest and Sinking Fund Report of December 31 for each year.

TABLE 82. FAIRFAX COUNTY WATER AUTHORITY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Operating expense ($)	707,901	884,487	1,096,406	1,345,317	2,317,132	2,890,859	3,229,023	3,456,438	3,937,701	4,432,271
Capital expense ($)	842,470	897,502	904,020	1,575,364	6,383,858	4,985,153	6,518,485	5,689,285	5,643,485	5,598,134
Interest	608.006	663,038	663,038	663,038	4,799,993	3,401,288	4,934,620	4,105,420	4,059,620	4,011,220
Total cost ($)	1,550,371	1,781,989	2,000,426	2,920,681	8,700,990	7,876,012	9,747,508	9,145,723	9,581,186	10,030,405
Operating expense as % of total	45.66	49.63	54.81	46.06	26.63	36.70	33.13	37.79	41.10	44.19
Capital expense as % of total	54.34	50.37	45.19	53.94	73.37	63.30	66.87	62.21	58.90	55.81

Locations of the Fairfax County Water Authority's facilities are shown in Figure 41.

To analyze the cost of water as it moves through acquisition to treatment to the customer, it is necessary to identify the capital and operating cost of each system component. Figure 42 is a schematic diagram of Figure 41 and shows the operating and capital costs for each of the system's major facilities. A linear assumption is made to allow unit cost ($/mil gal) to be added as water moves from one component of the system to another. For example, the cost of acquiring water from the Occoquan supply is $17.56/mil gal, and the cost of treating 1 mil gal of water is $61.54. The cost of pumping the water from the treatment plant into the distribution system and delivering it to Zone 1 is $24.95/mil gal. These costs added together make an incremental cost of $103.74/mil gal for water delivered to Zone 1. Incremental costs are shown in Table 83.

Added to the incremental costs are the distribution cost, the interest cost, and the support services cost. The distribution cost is calculated on the assumption that these unit costs are constant throughout the system; the total capital and operating cost for distribution is therefore divided by the number of gallons of RPW in the year under consideration, yielding a figure of $104.44/mil gal. The same approach is taken for interest and support services. When these are added together, a total unit cost/($/mil gal) for delivery to a given area results. For example, the total cost for delivering water to Zone 1 is $505.33/mil gal. Table 83 contains the metered consumption for each of the pressure areas and the estimated contribution for recovering the total cost.

Once these calculations are made and various cost zones are established, the costs versus charges can be examined. Tables 84 and 85 summarize the water consumption rates charged by the Fairfax County Water Authority.

Costs of water for the 10 largest consumers served by the Authority are shown in Table 86.

By dividing the mil gal used into the amount charged, it is possible to examine the actual unit charge ($/mil gal), as shown in the last column of Table 86.

Average unit cost for all water supplied during the most recent year studied is as follows:

	$/mil gal
Support services--------	88
Acquisition-------------	35
Treatment---------------	56
Distribution------------	134
Interest----------------	209
Total-------------------	522

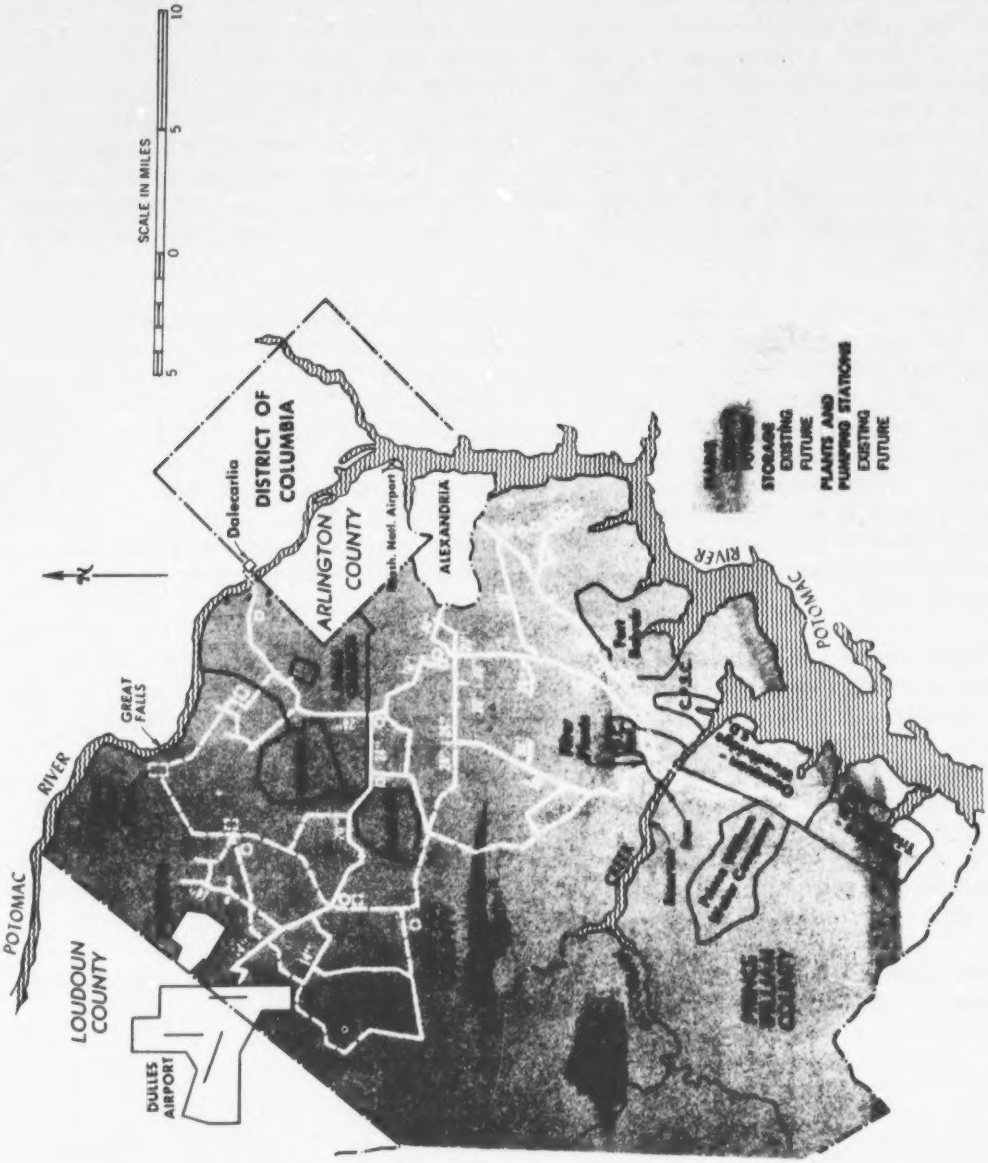

LOUDOUN COUNTY
DULLES AIRPORT
POTOMAC
RIVER
GREAT FALLS
N
Dalecarlia
DISTRICT OF COLUMBIA
ARLINGTON COUNTY
Wash. Natl. Airport
ALEXANDRIA
Fort Belvoir
POTOMAC
RIVER
PRINCE WILLIAM COUNTY
SCALE IN MILES
5
0
5
10
STORAGE
EXISTING
FUTURE
PLANTS AND PUMPING STATIONS
EXISTING
FUTURE

Figure 41. Fairfax County Water Authority principal supply and transmission facilities, 1967.

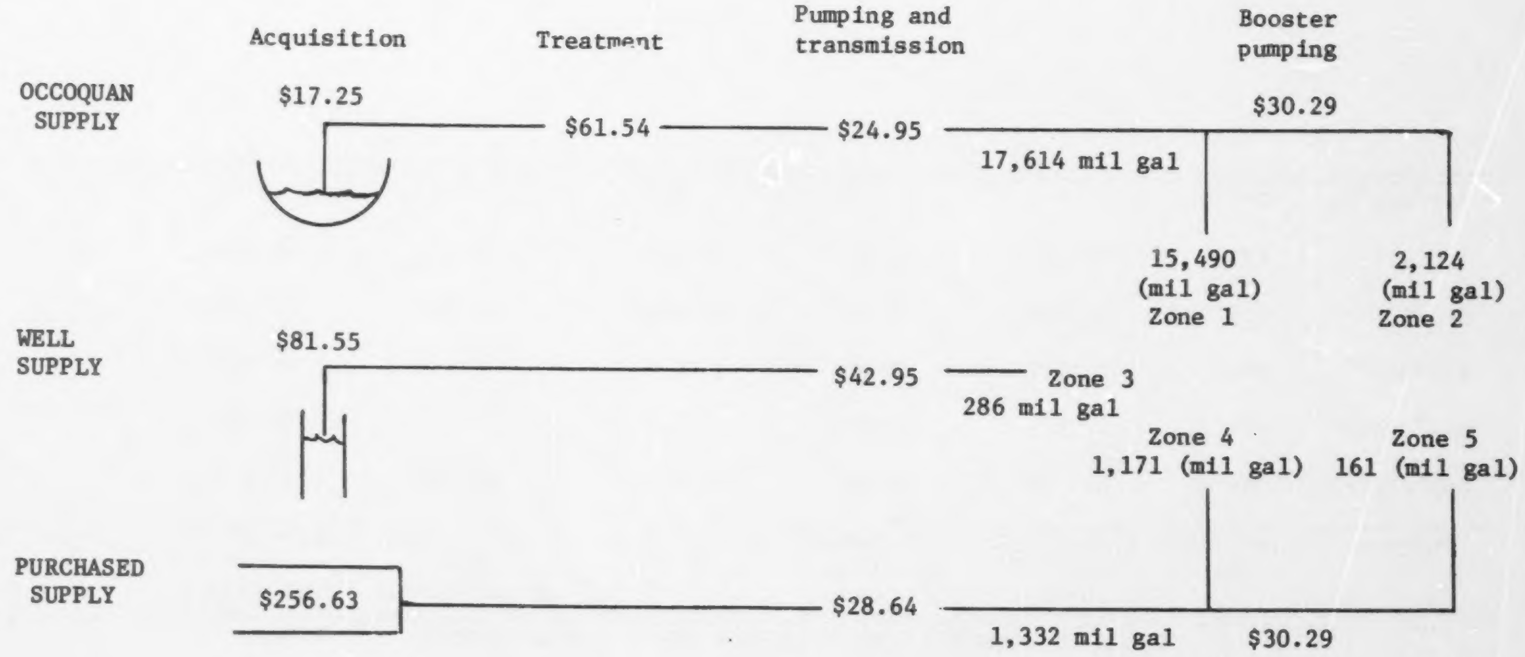

Acquisition
Treatment
Pumping and transmission
Booster pumping
OCCOQUAN SUPPLY
$17.25
$61.54
$24.95
$30.29
17,614 mil gal
15,490 (mil gal) Zone 1
2,124 (mil gal) Zone 2
WELL SUPPLY
$81.55
$42.95
Zone 3 286 mil gal
Zone 4 1,171 (mil gal)
Zone 5 161 (mil gal)
PURCHASED SUPPLY
$256.63
$28.64
1,332 mil gal
$30.29

Figure 42. Fairfax County Water Authority allocation of capital and operating expenses to water system components.

TABLE 83. FAIRFAX COUNTY WATER AUTHORITY COST ELEMENTS BY ZONES

Zone	Incremental cost ($/mil gal)	Distribution cost ($/mil gal)	Interest ($/mil gal)	Overhead ($/mil gal)	Total cost ($/mil gal)	RPW (mil gal)	Revenue
1	103.74	104.44	208.57	88.27	505.02	15,490	$7,822.760
2	134.03	104.44	208.57	88.27	535.31	2,124	1,136,998
3	124.50	104.44	208.57	88.27	525.78	286	150,373
4	285.27	104.44	208.57	88.27	686.55	1,171	803,950
5	315.56	104.44	208.57	88.27	716.84	161	115,411
Total	---	---	---	---	---	19,232	10,029,492

TABLE 84. FAIRFAX COUNTY WATER AUTHORITY METER RATES* ($/mil gal)

Meter size (in.)	Charge
5/8	$3.00
3/4	3.50
1	4.00
1½	5.25
2	6.50
3	15.00
4	25.00
6	45.00
8	70.00
10	100.00

* Commodity charge is $0.68/1,000 gallons.

TABLE 85. FAIRFAX COUNTY WATER AUTHORITY CHARGE ANALYSIS

Units used (cu ft x 100)	Gallons used	Commodity + Meter Charge
13.5	10,000	$14.71
5,000	3,740,260	5,500.38
100,000	74,805,200	110,007.65
150,000	112,207,800	165,011.47

TABLE 86. FAIRFAX COUNTY WATER AUTHORITY WATER COSTS FOR 10 MAJOR USERS

Major user	High or low quarter	Quarter	Consumption (mil gal)	Amount billed*	Unit charge ($/mil gal)	Cost zone†
Fairfax County Hospital	High	3	14.7	$10,048.32	$684.77	
	Low	1	1.2	894.84	737.71	
New Alex Dairy	High	4	9.8	6,655.54	680.66	
	Low	1	9.2	6,287.66	680.70	
Hazelton Labs	High	4	8.7	5,897.45	680.61	
	Low	3	6.0	4,066.21	680.88	
Woodley Mobile Homes	High	4	6.2	4,234.06	681.05	
	Low	3	1.0	715.74	686.23	
Oakland Manor Apartments	High	2	7.2	4,894.34	680.90	
	Low	3	5.7	3,872.98	681.14	
Fairfax County Hospital	High	3	6.6	4,565.48	690.59	
	Low	1	3.6	2,506.44	699.54	
Allen and Rocks, Inc.	High	3	6.9	4,684.22	680.94	
	Low	1	3.1	2,113.82	682.10	
Washington Real Estate	High	3	4.9	3,347.34	681.32	
	Low	2	4.1	2,800.62	681.58	
Allen and Rocks, Inc.	High	3	5.4	3,683.94	681.20	
	Low	1	3.6	2,426.62	681.83	
Charterhouse Motor Hotel	High	4	4.5	3,047.46	681.45	
	Low	1	2.3	1,565.06	682.84	

* Meter charge plus commodity charge at current rate.
† Could not be determined.

SECTION 11

PHOENIX WATER DEPARTMENT

The City of Phoenix (Maricopa County) lies in the south central part of Arizona in what is considered to be a water-short area. The county, which is also the SMSA boundry, had a population of 1.3 million in 1974. The retail service area of the Phoenix Water Department serves 794,542 persons. Estimates are that in this rapidly growing area, the population served will more than double by the year 2,000. Table 87 gives some facts pertaining to the system.

WATER SUPPLY SERVICE AREA

The retail service area for the Phoenix Water Department encompasses approximately 185 sq miles, and water is provided on a wholesale basis to other areas, increasing the total service area to approximately 280 sq miles (Figure 43). The present retail service area includes retail service to most of the incorporated area of the City of Phoenix (some small portions of the city are still served by private companies), some unincorporated areas around the city, and a portion of the City of Scottsdale, Arizona.

The elevations within the service area vary from a low of 940 ft to a high of 1,600 ft, and in some cases water must be moved over fairly long distances to provide service to the citizens. The population within the Phoenix Water Department's service area is increasing at a rapid rate, a trend that is expected to continue. In the future, it is anticipated that the Phoenix Water Department will expand by construction and by acquiring some of the smaller private companies in the area. By the year 2,000 its service area will increase to approximately 455 sq miles. The water department has placed major emphasis on developing a plan to meet future water needs through acquiring the water and providing the physical facilities for treatment and distribution.

ORGANIZATION

Organizationally, the Phoenix Water Department combines both water supply and wastewater treatment functions; the accounting systems for the two operations are also combined. Where an overlap in function occurred, it was necessary to estimate the cost assigned to each operation. The Phoenix Water Department organizational structure (Figure 44) is composed of two major sections: administration and operations. The administrative area accomplishes all tasks not associated with the direct production of water or wastewater and includes three divisions: Accounting, Engineering, and Technical

TABLE 87. PHOENIX WATER DEPARTMENT, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	1,306,000
County	1,306,000
Retail service area	794,542
Area of retail service area (sq miles)	185
Recognized customer classes (active accounts):	
Residential	172,503
Commercial	20,347
Industrial	142
Government	1,028
Flat rate (no. accounts)	400
Percent metered	100
Purchased water (raw, mil gal)	29,485
Source water	60% Surface - 40% Ground
Pipe in system (miles)	3,445
Elevation of treatment plants (ft above sea level datum):	
Verde	1,370
Deer Valley	1,228
Squaw Peak	1,390
Elevation of service area (min-max, ft)	940/1600
Revenue-producing water (mil gal)	63,661
Treated water (treated and well water, mil gal)	67,042
Maximum day/maximum hour (MGD)	323.8/449.0

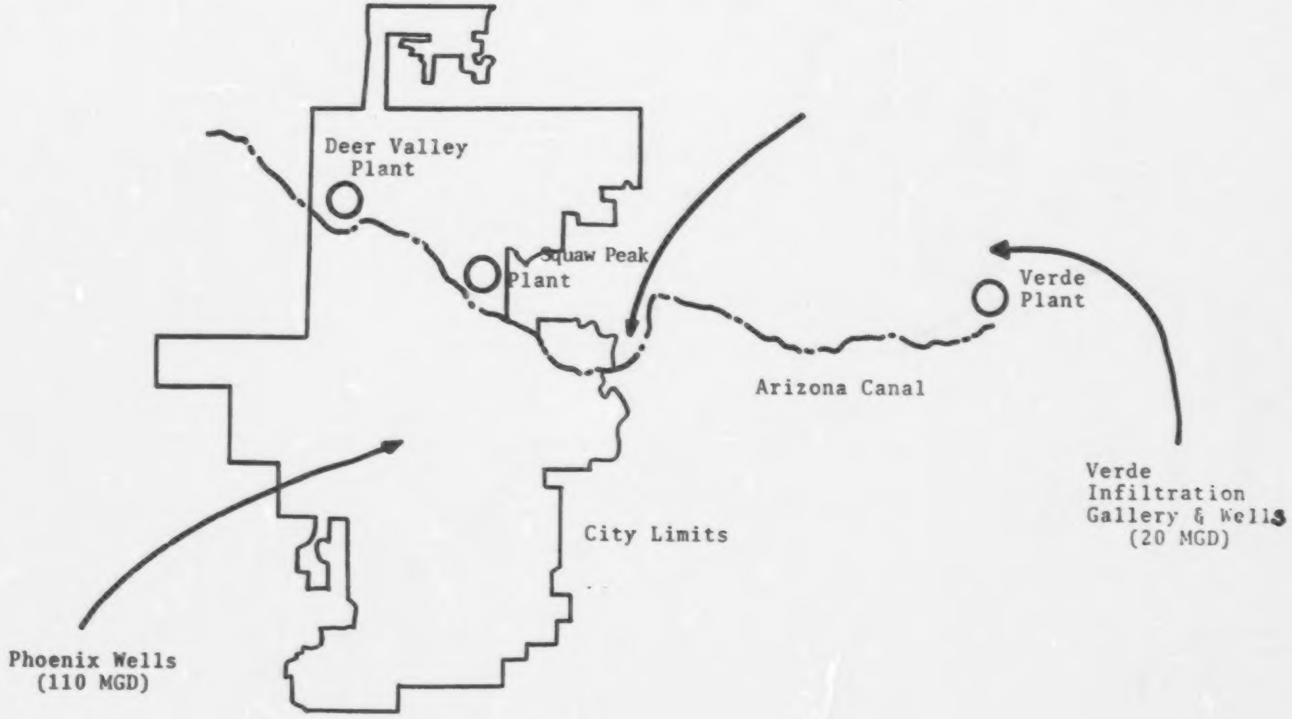

Deer Valley Plant
Squaw Peak Plant
Verde Plant
Arizona Canal
City Limits
Verde Infiltration Gallery & Wells (20 MGD)
Phoenix Wells (110 MGD)

Figure 43. Phoenix Water Department retail service area.

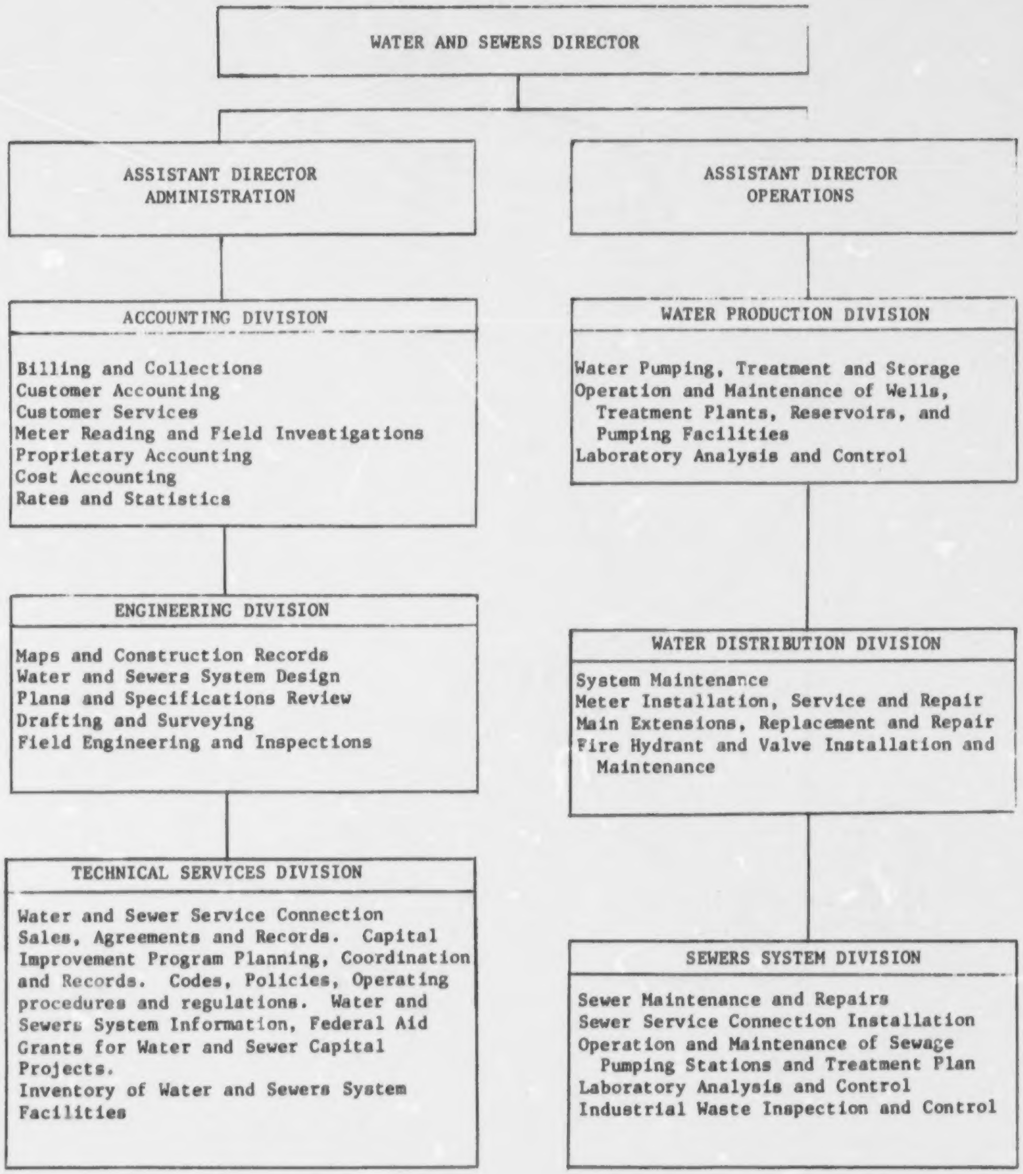

WATER AND SEWERS DIRECTOR
ASSISTANT DIRECTOR ADMINISTRATION
ASSISTANT DIRECTOR OPERATIONS
ACCOUNTING DIVISION
Billing and Collections
Customer Accounting
Customer Services
Meter Reading and Field Investigations
Proprietary Accounting
Cost Accounting
Rates and Statistics
ENGINEERING DIVISION
Maps and Construction Records
Water and Sewers System Design
Plans and Specifications Review
Drafting and Surveying
Field Engineering and Inspections
TECHNICAL SERVICES DIVISION
Water and Sewer Service Connection Sales, Agreements and Records. Capital Improvement Program Planning, Coordination and Records. Codes, Policies, Operating procedures and regulations. Water and Sewers System Information, Federal Aid Grants for Water and Sewer Capital Projects.
Inventory of Water and Sewers System Facilities
WATER PRODUCTION DIVISION
Water Pumping, Treatment and Storage
Operation and Maintenance of Wells, Treatment Plants, Reservoirs, and Pumping Facilities
Laboratory Analysis and Control
WATER DISTRIBUTION DIVISION
System Maintenance
Meter Installation, Service and Repair
Main Extensions, Replacement and Repair
Fire Hydrant and Valve Installation and Maintenance
SEWERS SYSTEM DIVISION
Sewer Maintenance and Repairs
Sewer Service Connection Installation
Operation and Maintenance of Sewage Pumping Stations and Treatment Plan
Laboratory Analysis and Control
Industrial Waste Inspection and Control

Figure 44. Phoenix Water Department organizational chart.

Services. The Operations Section, which performs the physical operations and maintenance for water supply and wastewater, also has three major divisions: Water Production, Water Distribution, and Sewer Systems. The function of each division is shown on Figure 44.

For the most part, the operations areas of the water supply and sewer services are reasonably well divided; in the administrative area, however, considerable overlapping of function occurs and it is necessary to estimate the portion of each service allocated to the water production. For example, all billing and collection for both water and sewer are accomplished through a common accounting system.

ACQUISITION

Raw water for the Phoenix Water Department comes from both surface and ground sources. Approximately 60% of the water used is surface water and 40% is groundwater.

The surface water for the Phoenix Water Department is obtained from two basic sources: the Salt and Verde Rivers.* The surface water is controlled by the Salt River Project, and there is a tight accountability for the water extracted from the source and ultimately returned to the water source system.

There are 110 wells with a total capacity of 155 MGD producing for the Phoenix Water Department. These wells are somewhat clustered in fields and are geographically distributed over portions of the area. Some wells are held in reserve for emergency use only.

Well water is used in two ways by the department: (1) water is pumped from the well, chlorinated, and moved directly into the transmission and distribution system; and (2) well water is pumped directly into canals controlled by the Salt River Project. This water is traded for surface water, which can be utilized at a different point in the water system or at a different time when the need may be greater. When well water is pumped into a canal above the city water department, a greater amount of water can be stored in the Salt River Project's reservoirs for release at a later time.

TREATMENT

Raw surface water is treated at three treatment plants with a total design capacity of 230 MGD. The Verde treatment plant (40 MGD) is located approximately 15 miles east of the city; Squaw Peak treatment plant, 110 MGD, is located on the Arizona Canal* at 24th Street near the center of the city; and Deer Valley treatment plant, 80 MGD, is located northwest of the city.

Figure 45 is a flow diagram of the Squaw Peak treatment plant. The other two treatment plants are similar to this system.

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* Arizona Canal water comes from the Salt and Verde Rivers.

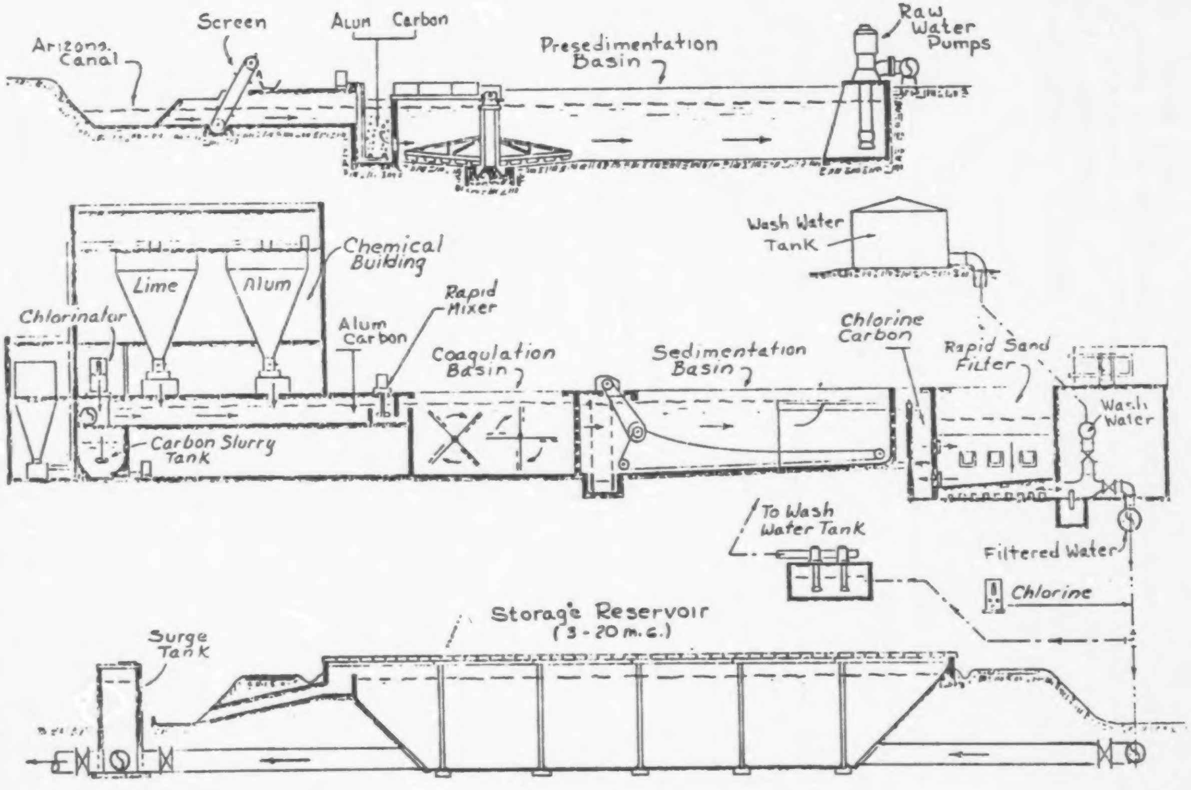

Arizona Canal
Screen
Alum
Carbon
Presedimentation Basin
Raw Water Pumps
Wash Water Tank
Chemical Building
Lime
Alum
Chlorinator
Alum Carbon
Rapid Mixer
Carbon Slurry Tank
Coagulation Basin
Sedimentation Basin
Chlorine Carbon
Rapid Sand Filter
Wash Water
To Wash Water Tank
Filtered Water
Chlorine
Storage Reservoir (3-20 m.c.)
Surge Tank

Figure 45. Squaw Peak Treatment Plant flow diagram.

TRANSMISSION AND DISTRIBUTION

The transmission and distribution system of the Phoenix Water Department consists of approximately 3,445 miles of underground pipe ranging from 2-in. pipe used for distribution to some of the residential areas up to 60-in. pipe used in some of the transmission lines.

The distribution system is divided into 21 separate service areas located within six pressure zones. Each 100 ft rise in elevation requires the establishment of a new pressure zone to provide the desirable range of water pressure to each customer. In every case, a higher service zone is serviced in whole or in part by pumps from the zone or zones below. Water delivered to some of the higher zones passes through several lower zones and has to be repumped as many as four times. The result is that each of the 21 service areas is interdependent and is affected by the water production capacity and rate of water consumption in other areas. The interrelationship of the 21 areas is complex, and the actual flow of water is controlled by hundreds of valves located throughout the system. At any given time, the interrelationship of the service areas and pressure zones is dependent on the valve setting configurations, making it extremely difficult to determine water flow. In the transmission and distribution system, there are 44 booster pumping stations and 25 storage reservoirs, which have a capacity of over 191 mil gal. In addition to these storage facilities, 31 booster stations with wells have a storage capacity of almost 13 mil gal. Table 88 lists the storage facilities and their capacities.

COST ANALYSIS

Growth in consumer demand for water from 1965 through 1974 is illustrated in Figure 46.

Using the standard cost categories, data were collected and reported as shown in Tables 89, 90, and 91. As indicated by the relative increase in the support services category, a major portion of the operating budget is expended for labor. Table 92 examines labor costs for operations and maintenance of the utility. The cost/man-hour increased by 122%, whereas the total payroll hours required to produce 1 mil gal of RPW decreased by 31%; thus the operating cost for producing water did not increase as rapidly as the labor cost/man-hour. However, at some future date it will no longer be possible to gain increasing efficiencies with respect to manpower, and the total payroll cost will increase at least at the same rate as the labor cost. Table 93 summarizes the operating, depreciation, and interest expenses for the 10-year period of the analysis. Capital and operating expense ratios are computed in Table 94. The operating expenses shown in Table 89 are costs incurred in the normal day-to-day operation of the system. The capital expenses are the total expenditures for providing major equipment items and facilities plus the interest charged on money borrowed for those purposes.

A comparison (Table 94) of the operating and capital expenses as a percent of the total cost shows that in the Phoenix Water Department, more expenses are associated with operations than with capital. Over the 10-year period, this trend continued to shift more heavily toward the operating

TABLE 88. PHOENIX SYSTEM STORAGE FACILITIES

Reservoir name	Capacity* (mil gal)	Elevation Overflow (ft)	Elevation Ground (ft)
Sweetwater and 18th St.	0.1	1,543	1,532
Cactus Rd. and 20th St.	1.0	1,629	1,601
Greenway Rd. and 16th St.	2.0	1,629	1,598
Lincoln Dr. and 36th St.	1.0	1,503	1,476
Cinnabar and 5th St. (2)	2.3	1,483	1,453
Hatcher Rd. and 18th St.	1.0	1,483	1,454
Mineral Rd. and 9th St.	1.0	1,468	1,437
Moon Mtn. and 18th Ave. (2)	4.15	1,452	1,430
Shaw Butte (2)	10.0	1,405	1,357
Squaw Pk. Wash Water	2.0	1,346	1,323
Papago Park (2)	3.0	1,462	1,430
Mineral Rd. and 9th St.	2.0	1,360	1,328
Olney and 15th Ave.	2.0	1,360	1,329
Thomas Rd. and 64th St. (3)	60.0	1,286	1,266
Squaw Peak Clearwell (3)	60.0	1,283	1,258
South Mountain	20.0	1,283	1,251
Deer Val Clearwell	20.0	1,228	1,203

* Total capacity of tanks at each location.

An additional 12.88 mil gal storage is distributed among 31 booster stations with the wells.

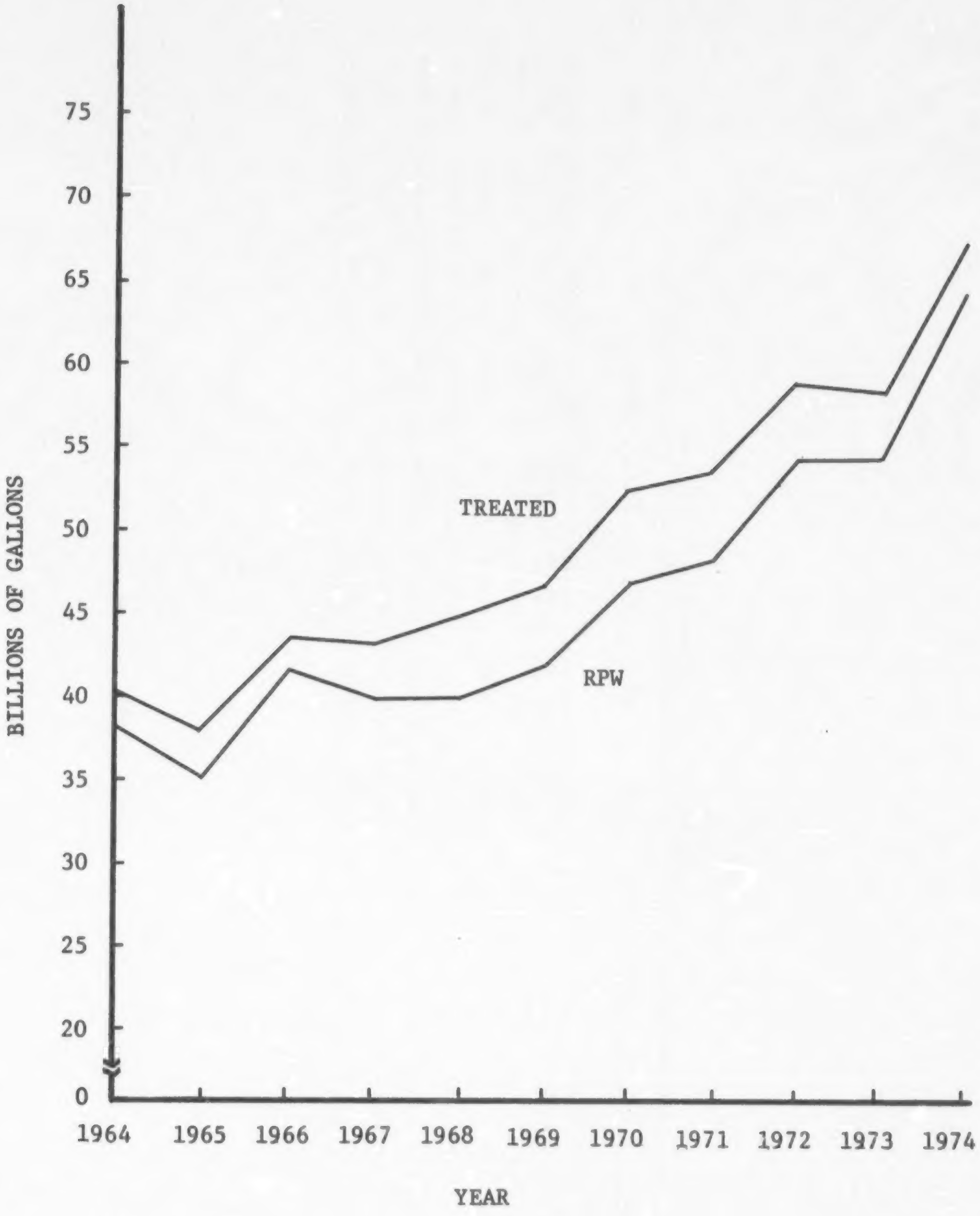


Figure 46. Phoenix Water Department water flow: treated water versus RPW.

TABLE 89. PHOENIX WATER DEPARTMENT ANNUAL OPERATING COSTS

Category	1965*	1966*	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	---	---	$ 589,212	$ 649,286	$ 692,791	$ 798,830	$ 903,020	$1,016,810	$1,134,421	$1,273,269
Accounting and collection	---	---	1,119,069	1,155,357	1,183,205	1,313,009	1,456,148	1,748,834	1,913,198	2,207,037
Other	---	---	1,112,676	1,212,944	1,420,457	1,514,275	1,601,935	1,693,404	1,760,845	1,831,773
Total support services	---	---	2,820,957	3,017,587	3,296,453	3,626,114	3,961,103	4,459,048	4,808,464	5,312,079
Acquisition	---	---	182,138	252,054	334,943	425,059	491,747	602,885	632,158	653,091
Treatment	---	---	875,362	930,437	1,007,997	1,151,044	1,331,632	1,421,131	1,634,991	1,630,577
Power and pumping	---	---	1,262,866	1,226,583	1,080,230	1,174,795	1,359,108	1,671,913	1,956,441	2,237,248
Transmission and distribution	---	---	1,024,055	1,225,687	1,283,099	1,539,713	1,773,444	1,960,999	2,211,966	2,628,261
Total operating cost	$5,299,336+	$5,731,336+	6,165,378	6,652,348	7,002,722	7,916,725	8,917,034	10,115,976	11,244,020	12,461,256

* Cost breakout for these years is not avaliable.

+ Estimated.

TABLE 90. PHOENIX WATER DEPARTMENT UNIT OPERATING COSTS ($/mil gal RPW)

Category	1965*	1966*	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	---	---	$14.93	$16.60	$16.84	$17.35	$19.11	$18.98	$21.35	$20.00
Accounting and collection	---	---	28.36	29.55	28.75	28.51	30.81	32.65	36.01	34.67
Other	---	---	28.20	31.02	34.52	32.88	33.90	31.61	33.14	28.77
Total support services	---	---	71.49	77.17	80.11	78.74	83.82	83.24	90.51	83.44
Acquisition	---	---	4.62	6.45	8.14	9.23	10.41	11.25	11.90	10.26
Treatment	---	---	22.18	23.79	24.50	24.99	28.18	26.53	30.78	25.61
Power and pumping	---	---	32.00	31.37	26.25	25.51	28.76	31.21	36.83	35.14
Transmission and distribution	---	---	25.95	31.34	31.18	33.43	37.53	36.61	41.64	41.29
Total unit operating cost	$152.31+	$139.10+	156.24	170.12	170.18	171.90	188.70	188.85	211.65	195.74

* Cost breakout for these years is not available.

+ Estimated.

TABLE 91. PHOENIX WATER DEPARTMENT OPERATING COST CATEGORIES AS PERCENT OF TOTAL COST

Category	1965*	1966*	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	---	---	9.56	9.76	9.89	10.09	10.13	10.05	10.09	10.22
Accounting and collection	---	---	18.15	17.37	16.90	16.59	16.33	17.29	17.01	17.71
Other	---	---	18.05	18.23	20.28	19.13	17.96	16.74	15.66	14.70
Total support services	---	---	45.76	45.36	47.07	45.81	44.42	44.08	42.76	42.63
Acquisition	---	---	2.95	3.80	4.78	5.37	5.51	5.96	5.62	5.24
Treatment	---	---	14.20	13.99	14.39	14.54	14.93	14.05	14.54	13.09
Power and pumping	---	---	20.48	18.44	15.43	14.84	15.24	16.53	17.40	17.95
Transmission and distribution	---	---	16.61	18.41	18.33	19.44	19.90	19.38	19.68	21.09
Total operating expense	---	---	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Cost breakout for these years is not available.

TABLE 92. PHOENIX WATER DEPARTMENT LABOR COST ANALYSIS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	2,039,599	2,426,455	2,454,856	2,769,303	2,852,055	3,089,632	3,586,964	4,774,176	5,237,496	5,743,024
Total hours on payroll	881,000	878,000	894,000	902,000	938,000	930,000	946,000	1,002,000	1,050,000	1,113,000
Revenue-producing water (mil gal)	34,794	41,203	39,459	39,104	41,148	46,054	47,255	53,566	53,126	63,661
Total payroll/mil gal ($)	58.62	58.89	62.21	70.82	69.31	67.09	75.91	89.13	98.59	90.21
Total hours RPW/mil gal	25.32	21.30	22.65	23.06	22.79	20.19	20.01	18.70	19.76	17.48
Average cost/man-hour ($)	2.32	2.76	2.75	3.07	3.04	3.32	3.79	4.76	4.99	5.16

TABLE 93. PHOENIX WATER DEPARTMENT CAPITAL AND OPERATING COST

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense	$5,299,336*	$5,731,336*	$6,165,378	$6,652,348	$7,002,722	$7,916,725	$8,917,034	$10,115,976	$11,244,020	$12,461,256
Depreciation	2,536,867	2,650,000*	2,868,063	2,984,716	3,152,513	3,319,446	3,474,388	4,013,693	4,182,875	4,524,535
Interest	2,135,831	2,215,029	2,364,290	2,326,628	2,317,427	2,343,740	2,145,752	2,077,064	2,542,319	3,419,045
Total	9,972,034	10,596,365	11,397,731	11,963,692	12,472,662	13,579,911	14,537,174	16,206,733	17,769,214	20,404,836
Total cost/mil gal RPW	286.60	257.17	288.85	305.94	303.12	294.87	307.63	302.55	338.24	320.52

* Estimates.

TABLE 94. PHOENIX WATER DEPARTMENT CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	5,299,336*	5,731,336*	6,165,378	6,652,348	7,002,722	7,916,725	8,917,034	10,115,976	11,244,020	12,461,256
Capital expense ($)	4,672,898	4,865,029*	5,232,353	5,311,344	5,469,940	5,663,186	5,620,140	6,090,757	6,725,194	7,943,580
Total ($)	9,972,234	10,596,365	11,397,731	11,963,692	12,472,662	13,579,911	14,537,174	16,206,733	17,969,214	20,404,836
Operating expense as % of total	53.14	54.08	54.09	55.60	56.14	58.29	61.33	62.41	62.57	61.07
Capital expense as % of total	46.86	45.92	45.91	44.40	43.86	41.71	38.67	37.59	37.43	38.93

* Estimates.

expense area. In 1965, the ratio was about 53% operating to 47% capital. This gradually changed to the point that in 1974, the ratio was 61% operating to 39% capital. During this time, there were no major capital expenditures, but labor costs increased drastically.

The Phoenix system is relatively old; therefore, the capital depreciated was expended when costs were significantly lower than at present. On the other hand, the operating expense is in current dollars. This ratio will change whenever major capital investments are made by the utility. For example, if a major modification to the treatment facility is required, capital expenses will increase without a corresponding increase in operating costs.

SYSTEM COSTS

Examination of the cost on a functional basis is only part of the total picture. Since the purpose of a water supply utility is to deliver water to a consumer, it is important to be able to present costs in such a way that they relate delivery of water to a demand point within the distribution system. The functional categories, both operating and capital, will therefore be reaggregated and assigned to physical components in the water delivery system. This section contains such an analysis of water supply system costs.

Figure 47 is a schematic presentation of the Phoenix Water Department supply system. As shown, the system is extremely complex, and because of the interdependence of the various service areas and pressure zones and the continual change in the water flowing within the system, it becomes impossible to accurately allocate costs and identify specific flow patterns of water through the physical components of the system. Therefore, a schematic diagram was not developed to identify operating and capital costs to the various physical components of the system.

Total unit costs for Phoenix were $320.52/mil gal RPW in 1974 (Table 93). This value includes all operating, depreciation, and interest costs associated with the utility's operation. It does not identify the costs of the specific components, but it does allow an overall evaluation of the cost to the department to produce water.

Though Phoenix is located in a water-short area, the charge for water usage (Tables 95 and 96) is relatively low--in fact, less than that charged in some areas that are not short of water.

The 10 top users of water from the Phoenix Water Department are listed in Table 97. Note that these major users are relatively low consumers of water as compared to the top 10 users of many other utilities across the United States. One reason is that Phoenix is considered a water-short area, and the city does not encourage industry requiring large volumes of water to locate in the vicinity.

Figure 48 shows the Phoenix service area and the locations of the top 10 users of the water. For the most part, they are clustered relatively close to the center of the total service area, and thus close to the Squaw Peak

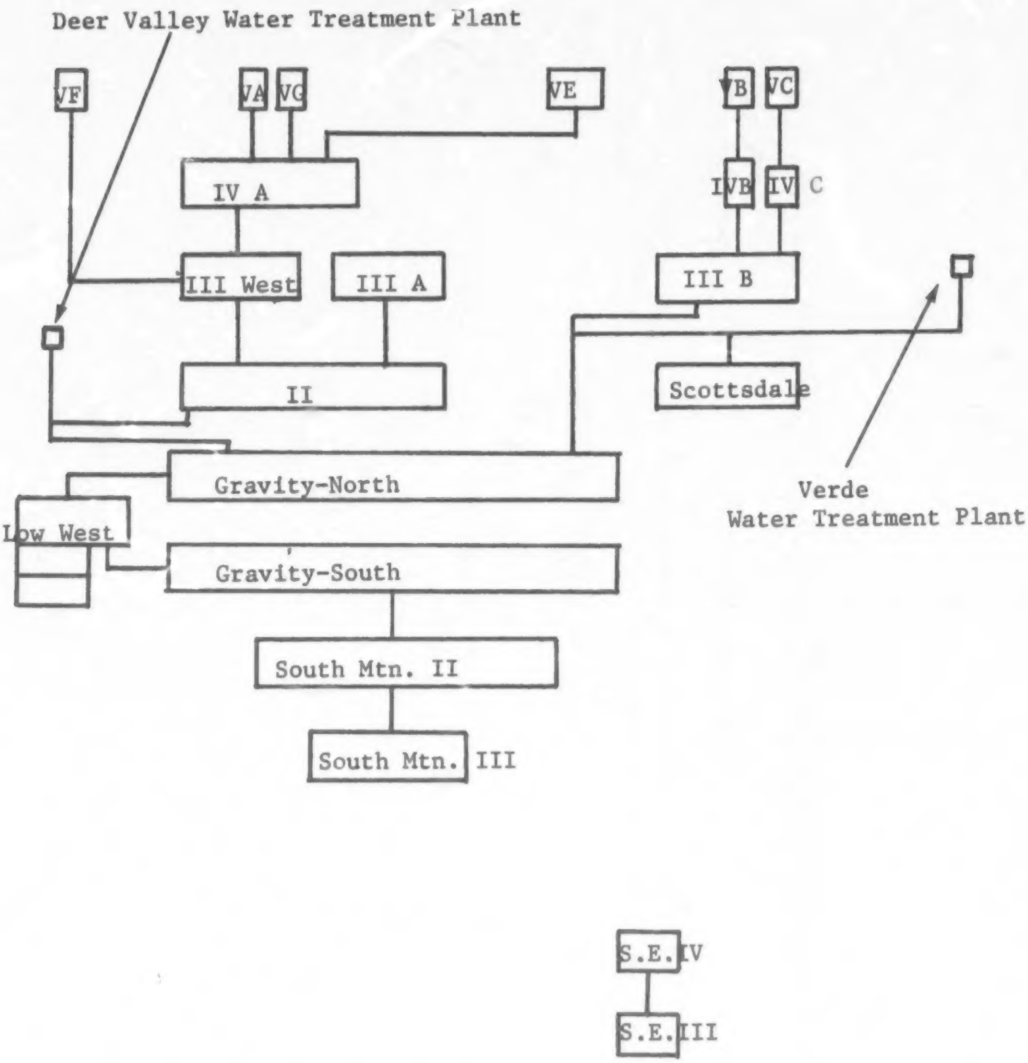

Deer Valley Water Treatment Plant
VF
VA
VG
VE
VB
VC
IV A
IVB
IV C
III West
III A
III B
II
Scottsdale
Gravity-North
Low West
Gravity-South
Verde
Water Treatment Plant
South Mtn. II
South Mtn. III
S.E. IV
S.E. III

Figure 47. Simplified Phoenix Waterworks schematic, 1975.

TABLE 95. PHOENIX WATER DEPARTMENT METER RATES EFFECTIVE JANUARY 1, 1974 (cu ft)

Inside city rates			Outside city rates			Scottsdale/ Paradise Valley rates		
Size of meter (in.)	Minimum allowance	Monthly rate	Size of meter (in.)	Minimum allowance	Monthly rate	Size of meter (in.)	Minimum allowance	Monthly rate
5/8 x 3/4	600	$3.30	5/8 x 3/4	600	$5.00	5/8 x 3/4	600	$4.00
1	800	4.35	1	800	6.50	1	800	5.20
1½	1,200	6.10	1½	1,200	9.15	1½	1,200	7.30
2	1,500	7.50	2	1,500	11.25	2	1,500	9.00
3	1,900	9.40	3	1,900	14.10	3	1,900	11.30
4	2,400	11.70	4	2,400	17.55	4	2,400	14.00
6	3,200	15.50	6	3,200	23.25	6	3,200	18.60

TABLE 96. PHOENIX WATER DEPARTMENT UNIT RATES (EFFECTIVE JANUARY 1, 1974)*

Quantity in excess of minimum allowance (cu ft)	Cost/100 cu ft	
	May thru Oct.	Nov. thru April
Inside city:		
Next 3,000	$0.21	$0.23
Next 57,000	0.20	0.22
Next 100,000	0.19	0.20
Next 140,000	0.18	0.18
Next 1,000,000	0.17	0.17
Next 2,000,000	0.15	0.15
Over 3,300,000	0.14	0.14
Outside city:		
Next 3,000	$0.30	$0.34
Next 57,000	0.29	0.33
Next 100,000	0.28	0.30
Next 140,000	0.27	0.27
Next 1,000,000	0.24	0.24
Next 2,000,000	0.22	0.22
Over 3,300,000	0.20	0.20
Scottsdale/Paradise Valley:		
Next 3,000	$0.25	$0.28
Next 57,000	0.24	0.26
Next 100,000	0.23	0.24
Next 140,000	0.22	0.22
Next 1,000,000	0.20	0.20
Next 2,000,000	0.18	0.18
Over 3,300,000	0.17	0.17

* Rates applicable for duplex, triplex, combination residential and/or commercial usage; trailer courts and churches, furnished upon request.

TABLE 97. PHOENIX WATER DEPARTMENT WATER COSTS FOR 10 MAJOR USERS

Major user	High or low month	Month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Cost zone
Pepsi Cola	High	Nov.	4.0	$985	$248.54	1
	Low	Jan.	3.2	803	253.87	
Arizona State Hospital	High	July	5.4	1,290	238.75	1
	Low	Feb.	2.2	674	310.59	
Honeywell	High	July	4.9	1,167	239.43	1
	Low	Jan.	2.3	598	263.32	
Air Research	High	Sept.	10.1	2,347	232.49	1
	Low	Dec.	4.0	1,001	247.95	
Coca Cola	High	June	5.1	1,216	237.68	1
	Low	Jan.	3.6	897	250.13	
Cudahy	High	Nov.	10.8	2,515	232.16	1
	Low	July	8.1	1,893	234.63	
Carnation	High	July	13.1	2.941	225.01	1
	Low	Feb.	9.3	2,195	236.04	
Reynolds Metals	High	May	23.5	5,034	214.26	1
	Low	Feb.	1.7	473	271.99	
Western Electric	High	June	14.6	3,256	222.63	1
	Low	Jan.	0.4	130	315.53	
Motorola	High	July	26.1	5,546	212.14	1
	Low	Aug.	13.6	3,053	224.27	

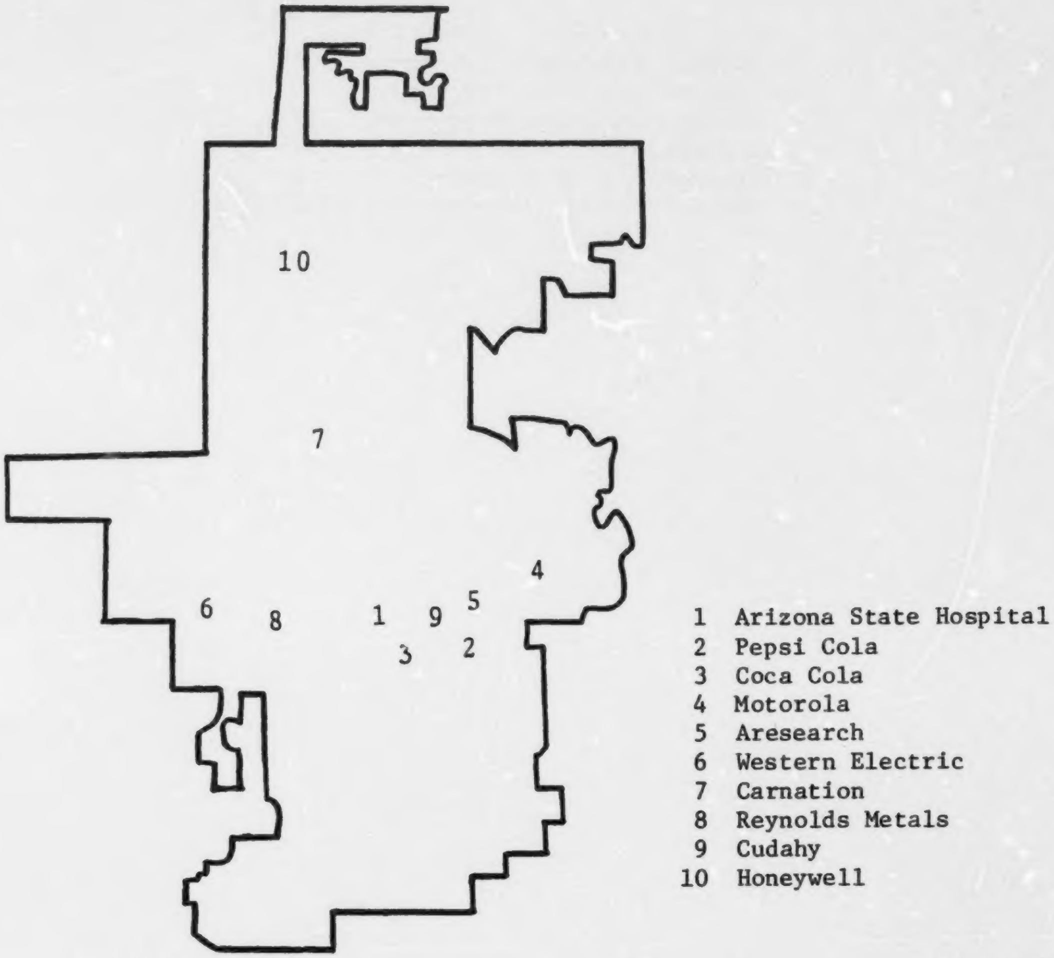

10
7
4
5
6
8
1
9
3
2
1 Arizona State Hospital
2 Pepsi Cola
3 Coca Cola
4 Motorola
5 Aresearch
6 Western Electric
7 Carnation
8 Reynolds Metals
9 Cudahy
10 Honeywell

Figure 48. Phoenix Water Department major users.

treatment plant and some of the well fields. This location means that the water delivered to them travels only a short distance and does not require the added cost of boosting to reach the extremity of the system.

The average unit costs for all water supplied during the most recent year studied are given as follows:

	$/mil gal
Support services	91
Acquisition	17
Treatment	47
Distribution	112
Interest	53
Total	320

SECTION 12

KENTON COUNTY WATER DISTRICT

The Kenton County Water District provides water to about 7,000 customers in the northwestern portion of Kenton County, Kentucky. The population in this area was 133,115 in 1974 and has shown only a slight increase over the past 10 years, allowing for the development of a relatively stable water utility. Some systems facts are shown in Table 98.

WATER SUPPLY SERVICE AREA

The water district provides water on a retail basis to all classes of customers in the service area shown in Figure 49. Treated water is supplied to 12 townships, an industrial park situated mainly outside the county, and unincorporated areas of Kenton County lying within the service area. In addition, water is supplied to the City of Florence and to the Boone County Airport, both located in Boone County but close to the population centers of Kenton County.

With a reasonably stable population, the emphasis is on maintaining the stability of the operating system from a cost/mil gal standpoint.

ORGANIZATION

Because the Kenton County Water District supplies water only, it is not intermingled with any other organization. The organization is headed by a general manager who reports directly to a three-man commission responsible for the operation of the water district.

Four divisions report to the general manager. Their responsibilities are: (1) treatment plant and laboratory operation and maintenance, (2) distribution system operations and maintenance, (3) accounting and collection, including meter service, and (4) engineering.

Because the organization is small (about 27 people), there is a tendency for one division to help another when the work load becomes heavy in a specific area. This does not affect the overall cost of the operation but may slightly shift cost allocations from one area to another. Figure 50 shows the organization of the Kenton County Water District.

TABLE 98. KENTON COUNTY WATER DISTRICT, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	1,424,596
County	133,155
Retail service area	7,000
Area of retail service area (sq miles)	40
Recognized customer classes (average no. of customers/year):	
Residential	12,773
Commercial	585
Industrial	59
Customer cities	1
Flat rate	0
Percent metered	100
Purchased water	None
Source water	100% surface
Pipe in system (miles)	157
Elevation of treatment plant (ft above mean sea level)	506
Elevation of service area (min-max ft)	520/910
Revenue-producing water (mil gal)	2,258.877
Treated water (pumpage from treatment plants +treated purchased water, mil gal)	2,356.97
Maximum day/maximum hour (MGD)	9/NA

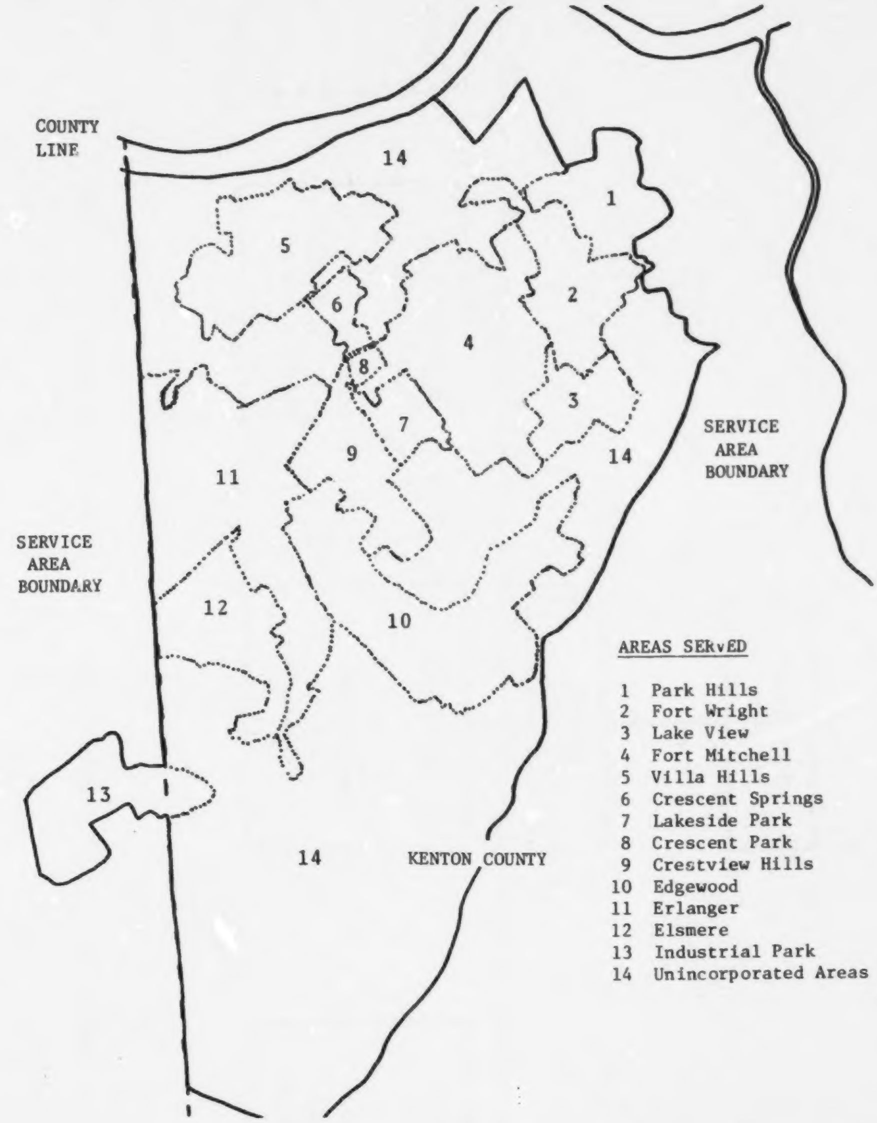

COUNTY LINE
14
1
5
2
6
4
8
3
7
9
14
SERVICE AREA BOUNDARY
11
SERVICE AREA BOUNDARY
12
10
13
14
KENTON COUNTY
AREAS SERvED
1 Park Hills
2 Fort Wright
3 Lake View
4 Fort Mitchell
5 Villa Hills
6 Crescent Springs
7 Lakeside Park
8 Crescent Park
9 Crestview Hills
10 Edgewood
11 Erlanger
12 Elsmere
13 Industrial Park
14 Unincorporated Areas

Figure 49. Kenton County Water District retail service area.

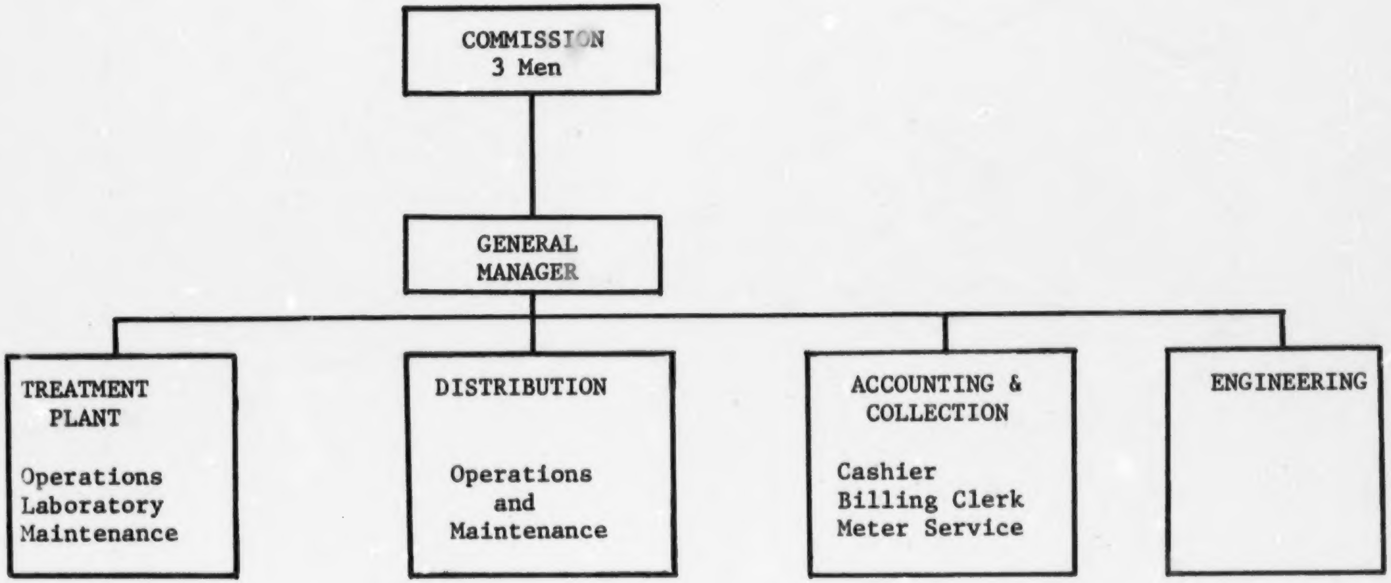

COMMISSION
3 Men
GENERAL
MANAGER
TREATMENT
PLANT
Operations
Laboratory
Maintenance
DISTRIBUTION
Operations
and
Maintenance
ACCOUNTING &
COLLECTION
Cashier
Billing Clerk
Meter Service
ENGINEERING

Figure 50. Kenton County Water District organizational chart.

ACQUISITION

Raw water comes from the Licking River and is transported a short distance to a single treatment plant where all raw water is treated. Intake facilities are located on the bank of the Licking River, approximately 5 miles upstream from the Ohio River, within the pool of the Markland Dam. Normal pool elevation maintained by the dam provides a water depth of 25 ft at the intake. The intake structure is a reinforced concrete tower that houses three electrical vertical turbine pumps--one 3.0-MGD and two 9.0-MGD. The intake facility is equipped with removable bar screens, motorized intake grates, traveling water screen, and adequate muck removal equipment.

TREATMENT

The treatment plant is located at the intersection of Grand and Howard Avenues in the city of Taylor Mill and performs three primary functions: clarification of raw water; removal of undesirable chemical characteristics (such as iron and manganese); and reduction of bacterial count. To accomplish these requirements, the plant includes facilities for storage and feeding of chlorine, alum, lime, activated carbon, and fluoride into the raw water. Basically, the plant cycle consists of prechlorination, chemical mixing, flocculation, clarification, filtration, and post-chlorination at a rated capacity of 12.0 MGD. There are eight mixed media filters. Figure 51 is a schematic diagram of the treatment facility.

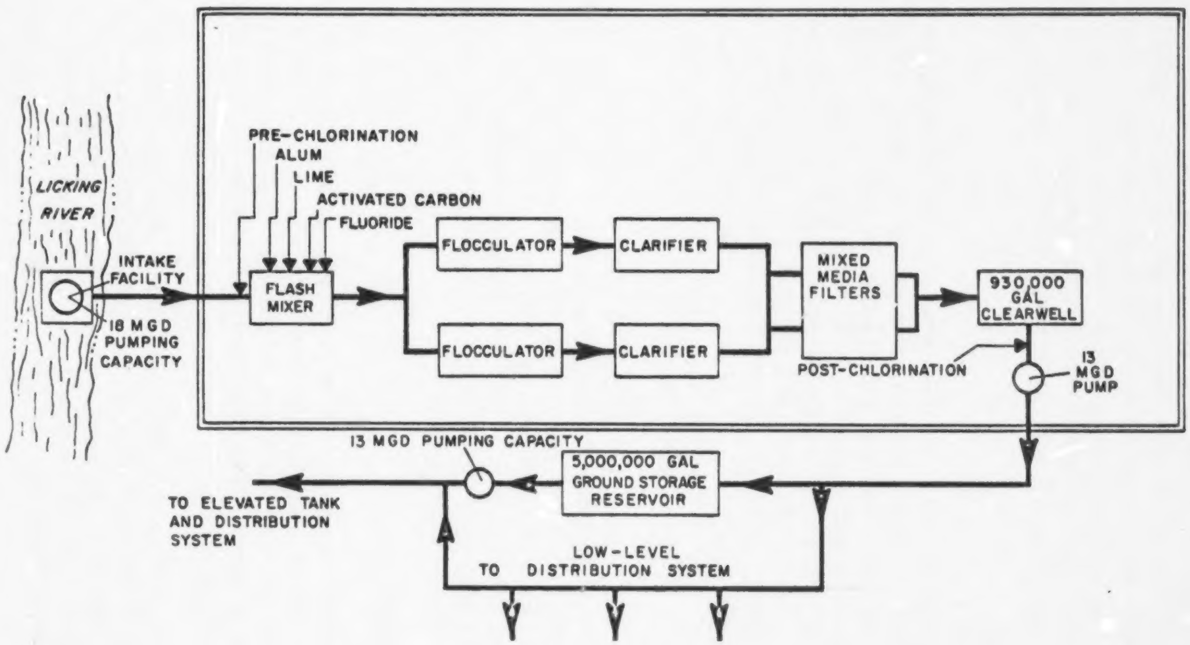
Physical, chemical, and bacteriological characteristics of the raw water vary greatly on a daily and seasonal basis, depending on numerous factors such as rainfall, temperature, flow rate, and the character of waste materials discharged upstream. Daily tests are run on samples of raw water, and the treatment process is modified as needed for changing conditions. Similarly, tests are run on the finished water samples to ensure that the objectives of the treatment process are met at all times.

TRANSMISSION AND DISTRIBUTION

The distribution system consists of approximately 157 miles of pipe in the ground. The 24-in. transmission pipe leading from the treatment plant is rapidly decreased to a 12-in. and then an 8-inch main, which constitutes the bulk of the transmission system. The distribution system is operated on three pressure levels or gradients.

The first pressure level is fed from a 5.0 MGD storage tank by gravity or by the pumping capacity at the treatment plant, which consists of one 3.0-MGD and two 5.0-MGD vertical turbine pumps. The 5.0-MGD ground storage tank located on the highest ground of the first pressure level is filled directly from the treatment facility.

The second pressure level, which is the largest and serves most of the communities in the service area, is supplied by gravity from three elevated storage tanks or by the capacity of the main booster pump station located at Dudley Pike. The pump station has three 4.5-MGD vertical turbine pumps that


LICKING RIVER
INTAKE FACILITY
18 MGD PUMPING CAPACITY
PRE-CHLORINATION
ALUM
LIME
ACTIVATED CARBON
FLUORIDE
FLASH MIXER
FLOCCULATOR
CLARIFIER
FLOCCULATOR
CLARIFIER
MIXED MEDIA FILTERS
930,000 GAL CLEARWELL
POST-CHLORINATION
13 MGD PUMP
13 MGD PUMPING CAPACITY
5,000,000 GAL GROUND STORAGE RESERVOIR
TO ELEVATED TANK AND DISTRIBUTION SYSTEM
LOW-LEVEL
TO DISTRIBUTION SYSTEM

Prepared by: NORTHERN KENTUCKY AREA PLANNING COMMISSION

Figure 51. Schematic diagram of the water treatment plant and distribution system for Kenton County Water District No. 1.

operate automatically based on the level existing in the elevated storage tanks. The pumps operate singly or in parallel, as required. The three elevated storage tanks have a combined capacity of 2.0 MGD.

The third pressure level is fed by gravity from two elevated storage tanks or by the two booster stations located on Turkey Foot Road at Lafayette Avenue. Each of these stations has a 1.0-MGD pump operated automatically off storage tank levels. The storage tanks have a combined capacity of 1.0 mil gal. Table 99 defines the storage capability of the Kenton County system.

COST ANALYSIS

The growth in consumer demand for water from 1965 through 1974 is illustrated in Figure 52.

Using the standard cost categories, data were collected and reported as shown in Tables 100, 101, and 102. Because a major portion of the operating budget was expended for labor, Table 103 was developed. The cost/man-hour increased by 52 percent over the 10-year period, whereas the man-hours required to produce 1 mil gal RPW decreased 40%. Thus, even though the hourly rate of pay increased significantly, the actual labor cost for producing 1 mil gal water decreased from $132.99/mil gal to $119.95/mil gal. The operating cost of production therefore did not increase as rapidly as the labor cost. In fact, the labor-related portion actually decreased. When it is no longer possible to gain increased efficiency with respect to manpower, the payroll cost will increase at least at the same rate as the labor cost.

Table 104 summarizes operating, depreciation, and interest expenses for the 10-year period of analysis. Table 105 computes capital and operating expense ratios. The operating expenses are those shown as the totals of the values in Table 100, the expenses incurred in the normal day-to-day operation of the system. The capital expenses are the total of periodic expenditures for major equipment and facilities plus the interest charged on money borrowed for those purposes.

A comparison of operating with capital expenses as a percent of the total cost shows that in the Kenton County system, more expenses are associated with operations than with capital. This 10-year trend resulted primarily from continued increases in the costs of items necessary to operations. Because only moderate capital costs were incurred during this period, the ratio of operating to capital expense maintained approximately the same relationship (70:30) throughout the 10 years studied.

The Kenton County system is relatively old; therefore, the capital depreciated was expended when costs were significantly lower than at present. On the other hand, the operating expense is in current dollars. This ratio will increase as capital investments are made by the utility. For example, a major capital expenditure may be required at the treatment facility to meet increasing demands. Should this occur, the ratio of capital expense to operating expense will increase significantly.

TABLE 99. KENTON COUNTY WATER DISTRICT STORAGE FACILITIES

Storage location	Type of storage	Base elevation (ft)	Overflow elevation (ft)	Capacity (mil gal)
Barrington Rd. in Lookout Heights - Fort Wright	Elevated tank	910.0	1,045.0	1.0
Dudley Pike	Ground storage tank	831.0	876.0	5.0
Dudley Pike in Edgewood	Elevated tank	890.0	1,045.0	0.5
Kenton Lands Rd. in Erlanger	Elevated tank	896.0	1,045.0	0.5
Industrial Park in Florence	Elevated tank	945.5	1,084.0	0.5
Oblique Street in Florence	Elevated tank	937.0	1,084.0	0.5

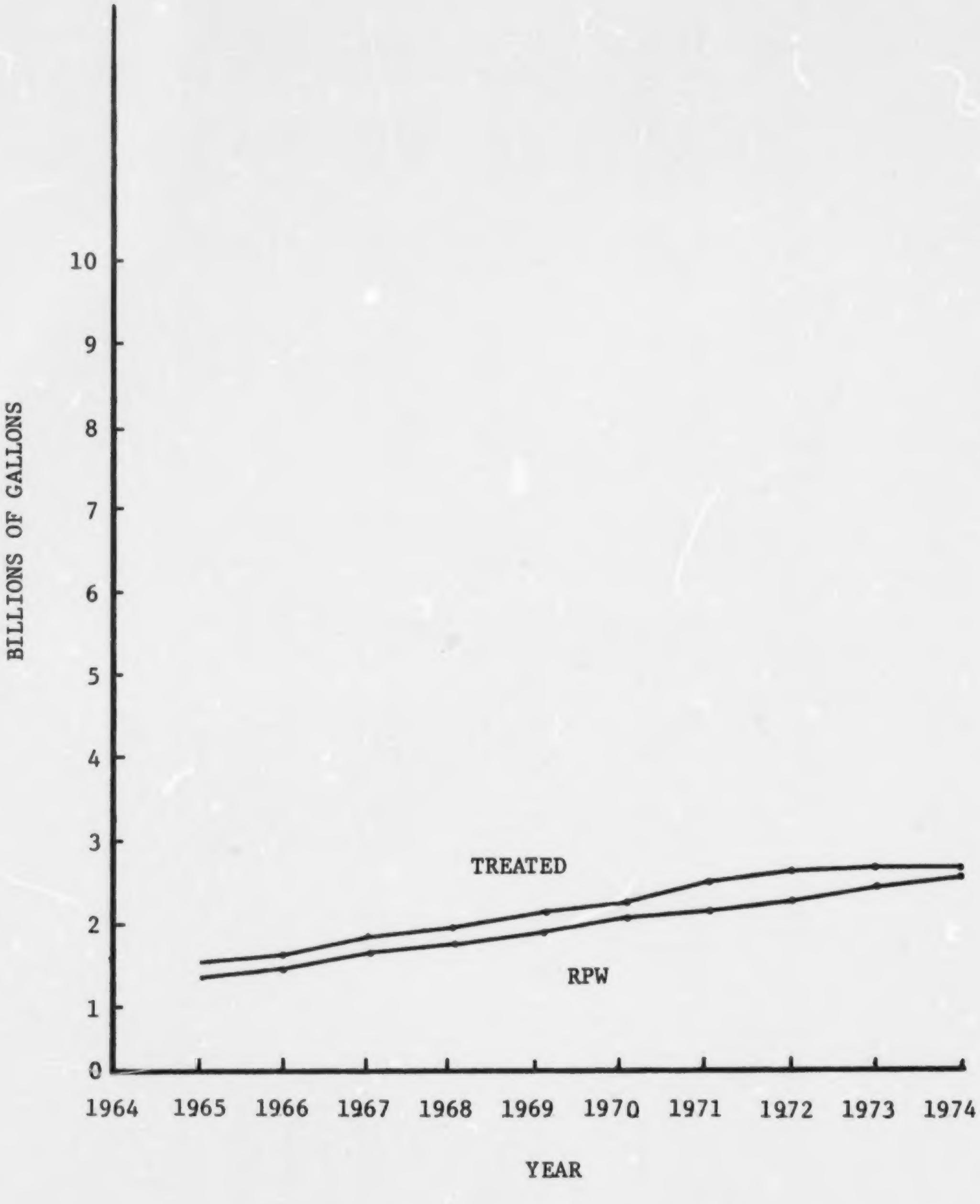


Figure 52. Kenton County Water District water flow: treated water versus RPW.

TABLE 100. KENTON COUNTY WATER DISTRICT ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$52,186	$44,383	$48,153	$47,651	$49,905	$50,119	$48,040	$55,814	$60,100	$64,565
Accounting and collection	22,811	27,147	27,309	32,095	37,599	41,088	61,945	66,733	72,671	80,525
Engineering	12,797	20,964	11,877	14,224	17,886	20,372	23,747	26,120	28,037	27,738
Total support services	87,794	92,494	87,339	93,970	105,390	111,579	133,732	148,667	160,808	172,828
Acquisition:	2,360	1,482	3,730	1,284	2,556	2,443	2,474	10,062	2,110	924
Treatment:										
Supervision and labor	25,738	25,822	27,547	29,848	32,806	34,321	36,955	38,082	40,017	40,454
Chemicals	26,902	28,808	31,677	27,618	30,335	37,415	34,402	37,564	38,081	49,213
Other	28,271	31,396	34,674	36,577	41,029	43,734	43,751	46,906	44,922	47,743
Total treatment	80,911	86,025	93,898	94,043	104,170	115,470	115,108	122,552	123,020	137,410
Power and pumping:										
Supervision and labor	3,601	3,603	3,814	3,962	4,046	4,185	4,643	4,679	4,903	4,937
Power	58,166	72,084	81,840	86,351	91,954	107,263	122,451	130,910	134,983	171,595
Maintenance and other	8,785	9,241	10,450	10,959	11,625	13,145	12,890	15,685	14,784	17,053
Total power and pumping	70,552	84,928	96,104	101,272	107,625	124,593	139,984	151,274	154,670	193,585
Transmission and distribution:										
Supervision and labor	6,667	6,601	6,980	5,807	3,612	3,347	4,834	4,035	4,117	3,979
Maintenance	31,120	30,412	35,285	35,528	34,915	46,394	40,464	67,246	45,358	65,447
Other	19,688	21,370	24,079	26,519	28,682	28,174	31,801	27,005	42,777	40,281
Total transmission and distribution	57,475	58,384	66,144	67,854	67,209	77,915	77,099	98,286	92,252	109,707
Total operating cost	299,092	323,313	347,215	358,423	386,950	432,000	468,397	530,841	532,860	614,454

TABLE 101. KENTON COUNTY WATER DISTRICT UNIT OPERATING COST ($/mil gal RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$45.86	$36.14	$34.87	$31.66	$30.71	$28.41	$25.44	$28.19	$27.93	$28.58
Accounting and collection	20.04	22.11	19.77	21.33	23.14	23.29	32.81	33.70	33.76	35.65
Engineering	11.25	17.07	8.60	9.45	11.01	11.55	12.58	13.19	13.03	12.28
Total support services	77.15	75.32	63.24	62.44	64.86	63.25	70.83	75.08	74.72	76.51
Acquisition:	2.07	1.21	2.70	0.85	1.57	1.38	1.31	5.08	0.98	0.41
Treatment:										
Supervision and labor	22.62	21.03	19.95	19.84	20.19	19.46	19.57	19.23	18.60	17.91
Chemicals	23.64	23.46	22.94	18.35	18.67	21.21	18.22	18.97	17.70	21.79
Other	24.84	25.56	25.10	24.30	25.24	24.79	23.18	23.69	20.87	21.13
Total treatment	71.10	70.05	67.99	62.49	64.10	65.46	60.97	61.89	57.17	60.83
Power and pumping:										
Supervision and labor	3.16	2.93	2.76	2.63	2.49	2.37	2.46	2.36	2.28	2.19
Power	51.12	58.70	59.26	57.38	56.59	60.81	64.85	66.12	62.72	75.96
Maintenance and other	7.72	7.53	7.57	7.28	7.15	7.45	6.83	7.92	6.87	7.55
Total power and pumping	62.00	69.16	69.59	67.29	66.23	70.63	74.14	76.40	71.87	85.69
Transmission and distribution:										
Supervision and labor	5.86	5.38	4.91	3.86	2.22	1.90	2.56	2.04	1.91	1.76
Maintenance	27.35	24.76	25.55	23.61	21.49	26.30	21.44	33.96	21.08	28.97
Other	17.30	17.40	17.44	17.62	17.65	15.97	16.84	13.64	19.88	17.83
Total transmission and distribution	50.51	47.54	47.90	45.09	41.36	44.17	40.84	49.64	42.87	48.56
Total unit operating cost	262.82	263.28	251.42	238.15	238.12	244.90	248.09	268.10	247.61	272.00

TABLE 102. KENTON COUNTY WATER DISTRICT OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	17.45	13.73	13.87	13.29	12.90	11.60	10.25	10.51	11.28	10.51
Accounting and collection	7.63	8.40	7.87	8.95	9.72	9.51	13.22	12.57	13.64	13.11
Engineering	4.28	6.48	3.42	3.97	4.62	4.72	5.07	4.92	5.26	4.51
Total support services	29.36	28.61	25.16	26.21	27.24	25.83	28.55	28.00	30.18	28.13
Acquisition:	0.78	0.46	1.07	0.36	0.66	0.57	0.53	1.90	0.40	0.14
Treatment:										
Supervision and labor	8.61	7.99	7.93	8.33	8.48	7.94	7.89	7.17	7.51	6.58
Chemicals	8.99	8.91	9.12	7.71	7.84	8.66	7.34	7.08	7.15	8.01
Other	9.45	9.71	9.99	10.20	10.60	10.12	9.34	8.84	8.43	7.77
Total treatment	27.05	26.61	27.04	26.24	26.92	26.72	24.57	23.09	23.09	22.36
Power and pumping										
Supervision and labor	1.20	1.11	1.10	1.11	1.05	0.97	0.99	0.88	0.92	0.80
Power	19.45	22.30	23.57	24.09	23.76	24.83	26.14	24.66	25.33	27.93
Maintenance and other	2.94	2.86	3.01	3.06	3.00	3.04	2.75	2.95	2.77	2.78
Total power and pumping	23.59	26.27	27.68	28.26	27.81	28.84	29.89	28.49	29.02	31.51
Transmission and distribution:										
Supervision and labor	2.23	2.04	1.95	1.62	0.93	0.77	1.03	0.76	0.77	0.65
Maintenance	10.41	9.41	10.16	9.91	9.02	10.75	8.64	12.67	8.51	10.65
Other	6.58	6.61	6.93	7.40	7.42	6.52	6.79	5.09	8.03	6.56
Total transmission and distribution	19.22	18.06	19.04	18.93	17.37	18.04	16.46	18.52	17.31	17.86
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 103. KENTON COUNTY WATER DISTRICT LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	151,360	157,208	159,593	171,120	191,812	207,238	223,933	242,152	200,249	271,302
Total hours on payroll	47,000*	48,500	55,450	53,300	46,750	49,900	57,258	57,641	56,480	55,529
Revenue-producing water (mil gal)	1,138	1,228	1,381	1,505	1,625	1,764	1,888	1,980	2,152	2,259
Total payroll/mil gal RPW ($)	133.00	128.01	115.56	113.70	118.03	117.48	118.63	122.29	93.05	120.09
Total hours/mil gal RPW	41.30	39.49	40.15	35.74	28.76	28.28	30.32	29.11	26.24	24.58
Average cost/man-hour ($)	3.22	3.24	2.87	3.18	4.10	4.15	3.91	4.20	3.54	4.88

* Estimated.

TABLE 104. KENTON COUNTY WATER DISTRICT CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expenses	$299,092	$323,313	$347,215	$358,423	$386,950	$432,000	$468,401	$530,841	$532,860	$614,454
Depreciation	16,339	26,600	32,118	34,676	37,835	47,458	58,907	58,664	67,142	110,771
Interest*	105,712	104,497	103,237	101,942	100,612	99,212	96,802	96,322	94,772	165,492
Total	421,143	454,410	482,570	483,833	525,397	578,670	624,110	685,827	694,774	890,717
Total cost/mil gal RPW	370.07	370.04	349.77	321.48	323.32	328.04	330.57	346.38	322.85	394.30

* Includes $72,280.00 for interest on bank notes in 1974.

TABLE 105. KENTON COUNTY WATER DISTRICT CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	299,092	323,313	347,215	358,423	386,950	432,000	468,401	530,841	532,860	614,454
Capital expense ($)	122,051	131,097	135,355	125,410	138,447	146,670	155,709	154,986	161,914	276,263
Total ($)	421,143	454,410	482,570	483,833	525,397	578,670	624,110	685,827	694,774	890,717
Operating expense as % of total	71.02	71.15	71.95	74.03	73.65	74.65	75.05	77.40	76.70	68.98
Capital expense as % of total	28.98	28.85	28.05	25.92	26.35	25.35	24.95	22.60	23.30	31.02

SYSTEM COSTS

Examination of costs on a functional basis is only part of the total picture. Because the purpose of the water utility is to deliver water to a customer, it is important to present costs as they relate delivery of water to a demand point within the system. For this reason, the functional categories, both operating and capital, are reaggregated and assigned to physical components in the system. This section contains such an analysis of the water supply system costs.

The locations of the Kenton County facilities are shown in Figure 53. The booster station (5) is where the Kenton County Water District connects with the Covington water utility and is considered an emergency water source.

To analyze the cost of water as it moves through acquisition to treatment to the consumer, it is necessary to identify the capital and operating cost of each system component. Figure 54 is a schematic diagram of Figure 53 and shows the operating and capital costs for each of the system's major facilities. A linear assumption allows the unit cost ($/mil gal) to be added as water moves from one component of the system to another. Total incremental cost is $157.01 for providing water to pressure zone 3 (see Table 106).

Added to the incremental costs are the distribution, interest, and support services costs. Distribution is calculated on the assumption that these unit costs ($/mil gal) are constant throughout the system; therefore, the total capital and operating cost for distribution is divided by the number of gallons of RPW in the year under consideration, yielding a figure of $92.91/mil gal. The same approach is taken for interest and support services. When these are added, a total cost/mil gal to a given zone results. For example, the total cost for water delivered to Area 3 is $404.81/mil gal.

Once these calculations are made and various cost zones are established, the costs versus charges can be examined. Table 107 summarizes the Kenton County Water Utility quarterly rates. Billed consumption of water for the 10 largest consumers served by the water district is shown in Table 108.

By comparing each user's location with the cost allocation table, it is possible to identify the actual allocated cost of delivering water to a specific customer. Figure 55 is a schematic presentation showing that many of the major users are located at the extreme limits of the system. Kenton County Water District is, for the most part, recovering the cost of producing the water. An exception is the City of Florence, which is the largest user.

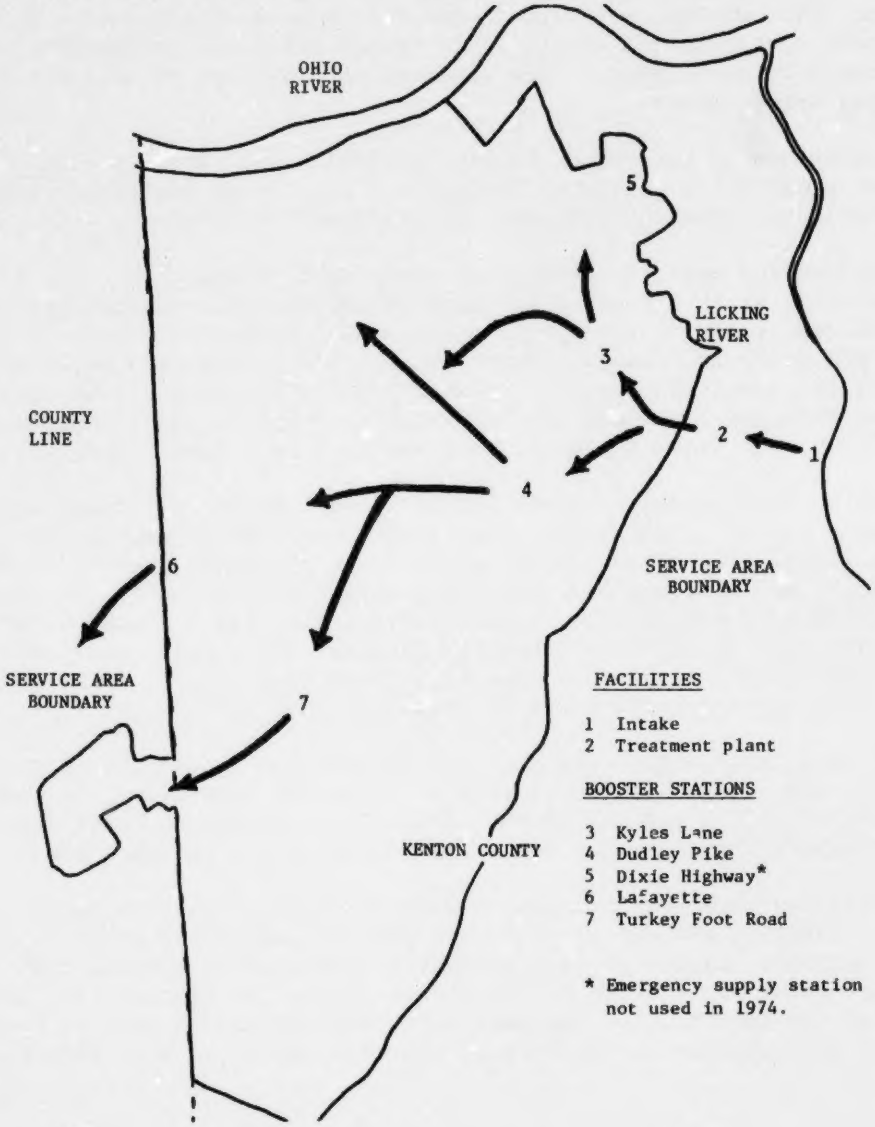

OHIO RIVER
5
LICKING RIVER
3
COUNTY LINE
2
1
4
SERVICE AREA BOUNDARY
6
SERVICE AREA BOUNDARY
7
KENTON COUNTY
FACILITIES
1 Intake
2 Treatment plant
BOOSTER STATIONS
3 Kyles Lane
4 Dudley Pike
5 Dixie Highway*
6 Lafayette
7 Turkey Foot Road
* Emergency supply station not used in 1974.

Figure 53. Kenton County Water District facilities (arrows show general direction of flow).

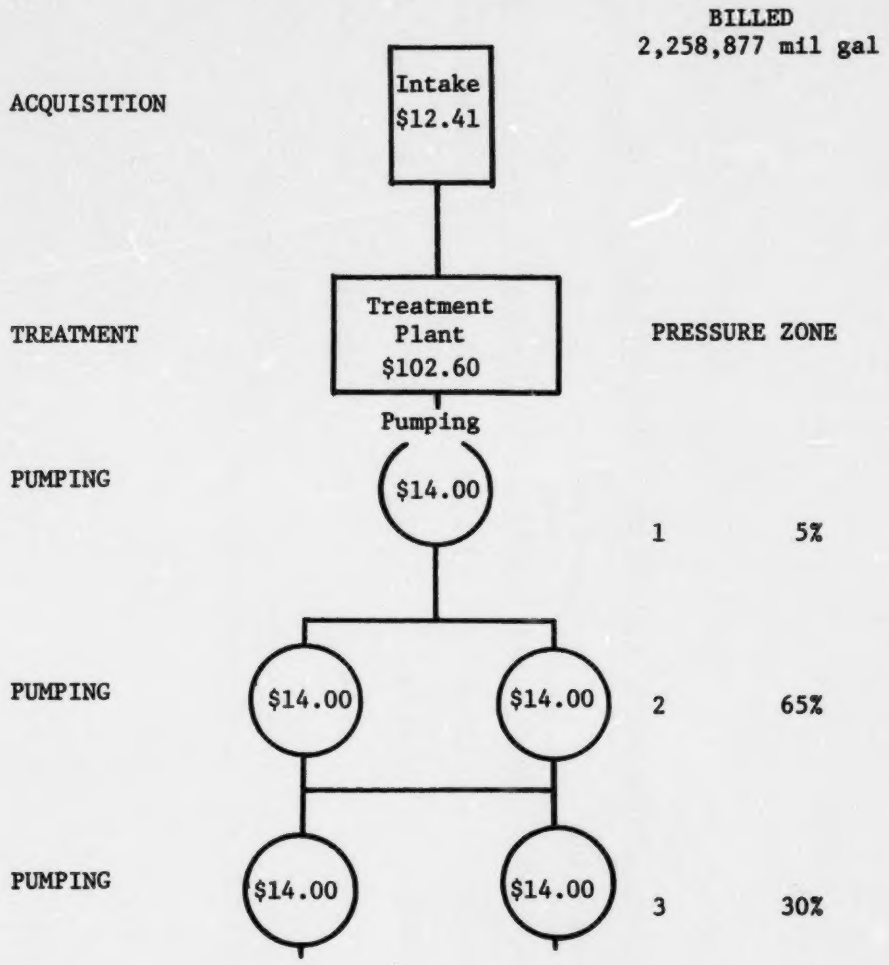

BILLED
2,258,877 mil gal
ACQUISITION
Intake
$12.41
TREATMENT
Treatment Plant
$102.60
PRESSURE ZONE
Pumping
PUMPING
$14.00
1
5%
PUMPING
$14.00
$14.00
2
65%
PUMPING
$14.00
$14.00
3
30%

Figure 54. Kenton County Water District allocation of capital and operating costs to water system components ($/mil gal RPW).

TABLE 106. KENTON COUNTY WATER DISTRICT COST ELEMENTS BY ZONES

Zone	Incremental cost ($/mil gal)	Distribution cost ($/mil gal)	Interest ($/mil gal)	Support services cost ($/mil gal)	Total cost ($/mil gal)	RPW* (mil gal)	Revenue
1	$129.01	$92.91	$73.26	$81.63	$376.81	112.94	$42,556.92
2	143.01	92.91	73.26	81.63	390.81	1,468.28	573,818.51
3	157.01	92.91	73.26	81.63	404.81	677.66	274,323.54
Total	---	---	---	---	---	2,258.88	890,698.97

* No flows available. Based on 5% area 1, 65% area 2, 30% area 3.

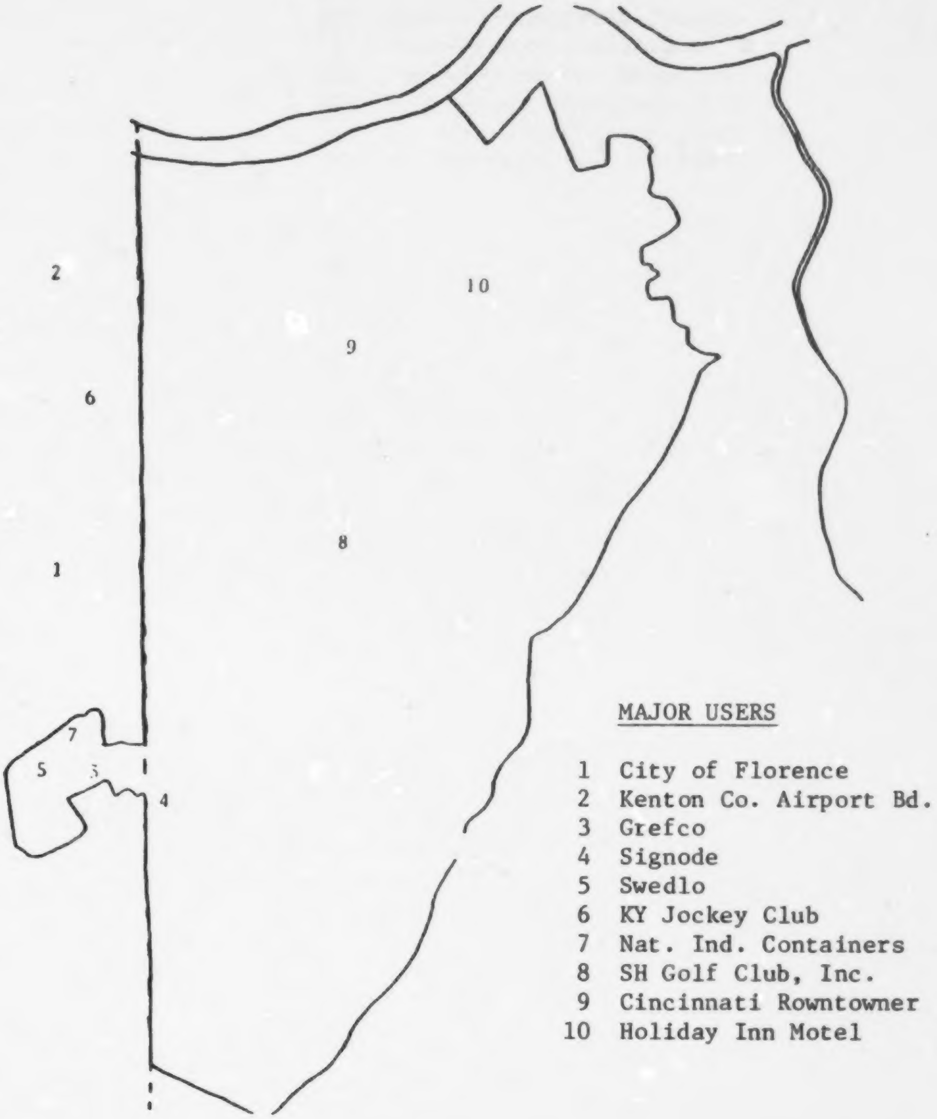
TABLE 107. KENTON COUNTY WATER DISTRICT NO. 1 QUARTERLY RATES

Units used (cu ft)	Rate ($/cu ft)
First 800	$0.50*
800-5,000	.40
Over 5,000	.30

* Minimum is $4.

TABLE 108. KENTON COUNTY WATER DISTRICT 10 MAJOR USERS

Major User	High or low Quarter	Quarter	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Cost zone
City of Florence	High	3	121.4	$35,316.12	$290.89	3
	Low	1	104.21	31,178.82	299.18	
Kenton Co. Airport Bd.	High	3	28.4	8,390.50	295.59	2
	Low	1	9.5	3,827.80	401.68	
Grefco, Inc.	High	3	17.2	6,886.20	401.07	3
	Low	2	14.9	5,962.20	401.07	
Signode Corporation	High	2	12.3	4,937.80	401.54	3
	Low	4	7.9	3,177.10	401.80	
Swedlo	High	2	10.3	4,150.90	401.63	3
	Low	1	7.4	2,982.70	401.85	
KY Jockey Club	High	2	9.8	3,954.40	401.66	2
	Low	3	6.5	2,615.20	401.96	
Nat. Ind. Containers	High	2	7.0	2,821.00	401.90	3
	Low	4	5.6	2,257.90	402.10	
S H Golf Club, Inc.	High	2	6.7	2,691.40	401.94	2
	Low	4	0.5	186.70	413.93	
Cincinnati Rowntowner	High	3	5.9	2,371.30	402.05	2
	Low	1	3.1	1,258.00	402.93	
Holiday Inn Motel	High	3	5.8	2,353.30	402.06	2
	Low	1	4.1	1,642.60	402.49	



MAJOR USERS

1 City of Florence
2 Kenton Co. Airport Bd.
3 Grefco
4 Signode
5 Swedlo
6 KY Jockey Club
7 Nat. Ind. Containers
8 SH Golf Club, Inc.
9 Cincinnati Rowntowner
10 Holiday Inn Motel

Figure 55. Kenton County Water District major users.

The average unit costs for all water supplied during the most recent year studied are given as follows:

	$/mil gal
Support services	82
Acquisition	12
Treatment	103
Distribution	124
Interest	73
Total	394

SECTION 13

ORLANDO WATER UTILITY

The City of Orlando in Orange County is located in the central part of the State of Florida. In 1974, the population of the county was 422,190, and the City of Orlando was just over 100,000. The projected growth rate of the Orlando metropolitan area is one of the highest in the nation, but the actual increase is falling short of the projections. As a mater of fact, county population decreased slightly between 1974 and 1975. The City of Orlando is surrounded in part by other incorporated areas, but room exists for growth to the south, east, and southwest. Table 109 includes system facts.

WATER SUPPLY SERVICE AREA

The Orlando Water Utility provides water on a retail basis to all classes of customers in the city and to a relatively large group of customers outside the city. All service outside the city limits is on an individual basis and is billed directly by the utility. No water is sold through master meters to other utilities.

The utility does not plan to provide water to all citizens in the county. Its expansion now and in the future will be on a case-by-case basis as deemed worthwhile to both the consumer and the utility. Figure 56 illustrates the service area boundaries.

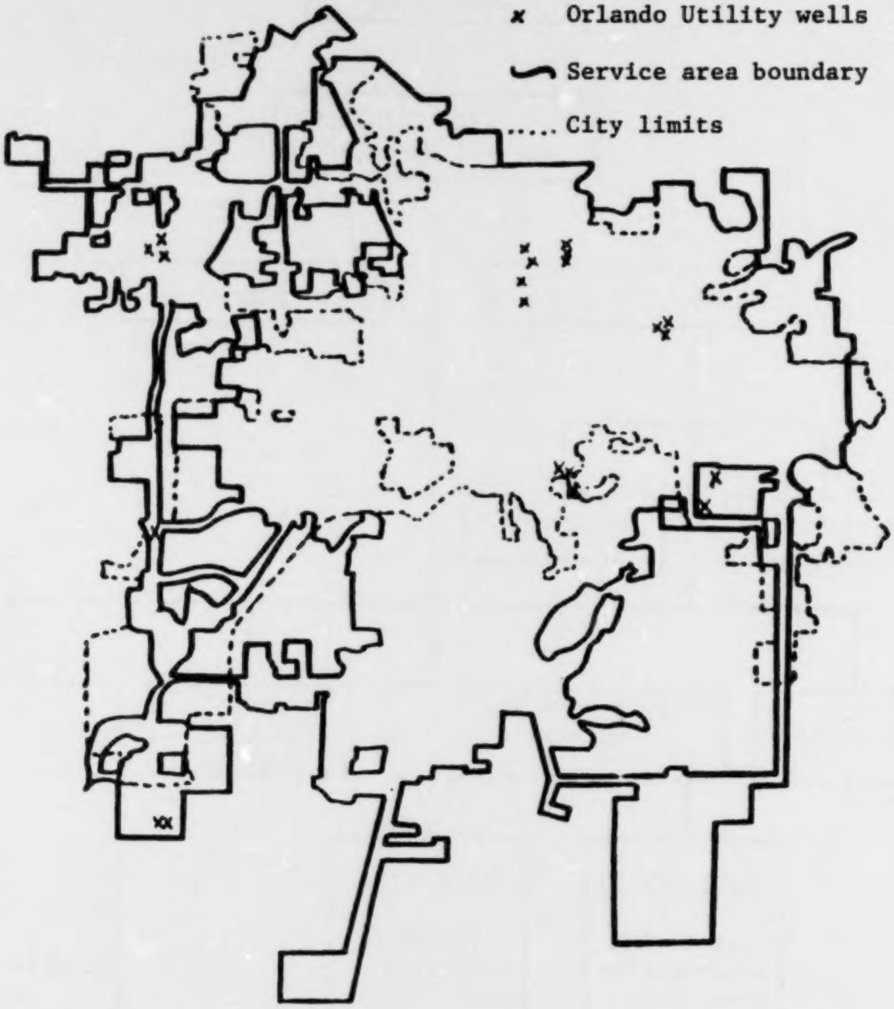
ORGANIZATION

Through the Orlando Utilities, the City of Orlando provides both electricity and water to the citizens of the city and selected areas surrounding the city. The Orlando Utilities is managed by a commission reporting directly to the mayor and city council. An executive vice president and general manager are responsible for the total utilities operation. Although two separate services are involved in the organization and some specific functions are shared between the electric and the water service, other functions are completely independent. Figure 57 depicts the organizational structure of the Orlando Utilities.

As can be seen, functions such as financial operations, customer relations, and support operations are shared between the two services. The combined operations of these functions were reviewed with the utility to estimate the percentage of effort in each department that could be allocated to water. Twenty percent of the financial operations and 45% of the customer

TABLE 109. ORLANDO WATER UTILITY, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	598,692
County	422,190
Retail service area	188,652
Area of retail service area (sq miles)	90
Recognized customer classes (No. of accounts)	
Total metered customers	62,884
Percent metered	100
Purchased water	None
Source water	100% ground water
Pipe in system (miles)	958.8
Elevation of treatment plants (ft above sea level datum):	
Kirkman	99
Highland	87
Primrose	108
Pine Hills	113
Kuhl	98
Martin	102
Conway	108
Elevation of service area (min/max, ft)	75/120
Revenue-producing water (billed consumption, mil gal)	12,522
Treated water pumpage from plants (mil gal)	14,880
Maximum day/maximum hour (MGD)	73/108



× Orlando Utility wells
Service area boundary
..... City limits

Figure 56. Orlando Water Utility source water map.

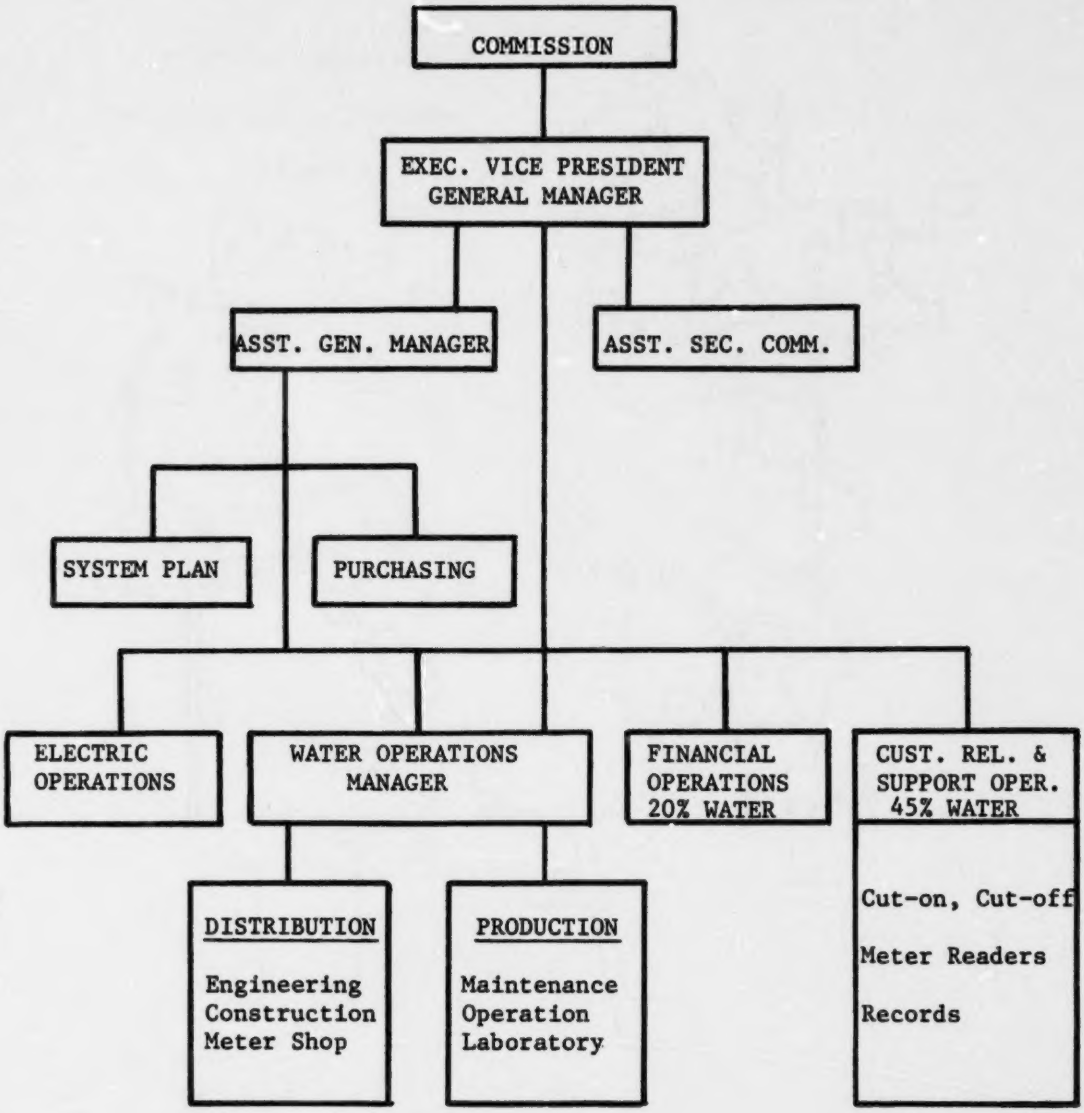

COMMISSION
EXEC. VICE PRESIDENT
GENERAL MANAGER
ASST. GEN. MANAGER
ASST. SEC. COMM.
SYSTEM PLAN
PURCHASING
ELECTRIC OPERATIONS
WATER OPERATIONS MANAGER
FINANCIAL OPERATIONS 20% WATER
CUST. REL. & SUPPORT OPER. 45% WATER
Cut-on, Cut-off
Meter Readers
Records
DISTRIBUTION
Engineering
Construction
Meter Shop
PRODUCTION
Maintenance
Operation
Laboratory

Figure 57. Orlando Water Utility organization chart.

relations and support operations were allocated to the function of water supply.

The major part of the water effort is accomplished under the water operations manager, who is responsible for all functions relating to acquiring, treating, and distributing water.

ACQUISITION

In the past, the Orlando utility obtained raw water from several lakes located in the city, moved the water through a treatment plant, and distributed it to the citizens. Because an abundance of high quality water was found to be available through deep wells reaching into the second aquifer directly under the city, the utility switched from the surface water to groundwater. The groundwater requires little treatment, and the wells are dispersed across the distribution area, so water is transported over short distances only.

All water is provided from 22 wells in the range of 2,000 ft deep. The source water is projected to meet the needs of the utility for the next 50 years. To meet the flow requirements, however, additional wells must be added.

TREATMENT

Because the source water is of high quality, only minimum treatment is necessary, and this takes place at the well or well fields. The water brought up from the well goes through an aerator to remove hydrogen sulfide, which gives the water an undesirable odor. Following aeration, chlorine is added to disinfect the water. For health purposes, fluoride is also added to the water. Figure 58 is a diagram of a treatment facility.

TRANSMISSION AND DISTRIBUTION

The Orlando system contains 958.8 miles of underground pipe. Most of this pipe is considered to be the distribution system as opposed to the transmission system. Transmission in the system is greatly reduced because of the geographical distribution of the well fields. Under normal operating conditions, the water is transported over relatively short distances. Each of the well fields is interconnected. The system is capable of functioning adequately with some of the wells down for maintenance.

The terrain of the service area is relatively flat, with a minimum elevation of 75 ft and a maximum elevation of 120 ft. At each well field there is a ground reservoir for storing water and an elevated storage tank to maintain pressure in the system. There are seven ground storage reservoirs and seven elevated storage tanks. All of the elevated storage tanks are 0.5 mil gal capacity, with the exception of one located at Copeland with a capacity of 1 mil gal. Total elevated storage capacity is 4 mil gal. Five ground storage reservoirs hold 2 mil gal each--one located at Highland holds

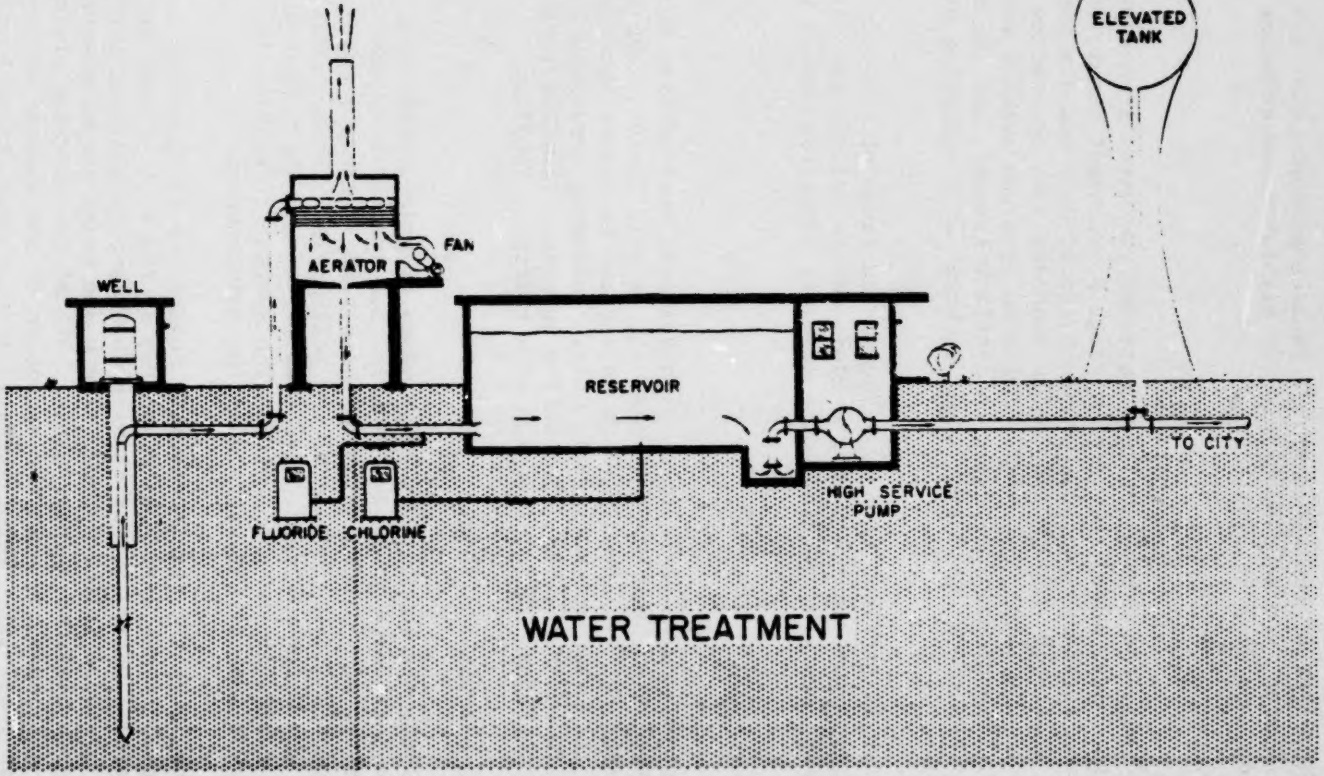

ELEVATED TANK
WELL
AERATOR
FAN
RESERVOIR
FLUORIDE
CHLORINE
HIGH SERVICE PUMP
TO CITY
WATER TREATMENT

Figure 58. Orlando Water Utility flow diagram.

3.5 mil gal, and one at Martin holds 1 mil gal. The combined ground storage capacity is 14.5 mil gal. Tables 110 and 111 include information on system storage.

COST ANALYSIS

The growth in consumer demand for water from 1965 through 1974 is illustrated in Figure 59. Revenue-producing water increased from 7,754 mil gal in 1965 to 12,522 mil gal in 1974. These figures reflect the amount of water billed to consumers during a given year. Treated water shown in the figure is the amount of water pumped from the wells for use by the city.

Using the standard cost categories, data were collected and reported as shown in Tables 112, 113, and 114. As indicated by the relative increase shown in support services, a major portion of the operating budget is expended for labor. Table 115 examines labor costs of operation and maintenance of the utility.

Table 115 shows total payroll hours required to produce 1 mil gal of RPW has remained approximately constant; therefore, one of the major influences in the increased cost of producing water is the increased labor cost.

Table 116 summarizes the operating, depreciation and interest expenses for the 10-year period of analysis. Table 117 computes capital and operating expenditure ratios. The operating expenses are those shown as a total of the values on Table 112--those incurred in the normal day-to-day operation of the system. The capital expenses are the total expenses for providing major equipment items and facilities plus the interest charged on money borrowed for those purposes.

A comparison of the operating and capital expense as a percentage of the total shows that at present, more expenses are associated with operations than with capital. At the beginning of the 10-year period, the ratio was approximately even between operating and capital expenses. Since that time, increasing costs of operation have changed the ratio.

In 1974, the ratio of 63% operations to 37% capital outlay reflected major investments made in years before the analysis. Slight increases in capital expenditures reflected only minor adjustments to the system. During the same period, a considerable increase occurred in the operating area because of increased man-hours and increased costs/man-hour. This, along with other increased operating costs, caused a more rapid increase in the operation and maintenance area than in the area of capital expense.

SYSTEM COSTS

Examination of costs on a functional basis is only part of the total cost picture. Because the purpose of a water supply utility is to deliver water to a customer, it is important to present costs as they relate water delivery to a demand point in the system. For this reason, functional categories, both operating and capital, are reaggregated and assigned to physical

TABLE 110. ORLANDO WATER UTILITY ELEVATED WATER STORAGE.

Location	Ground elevation+ (ft)	Capacity (mil gal)	Overflow elevation (ft)
Oakridge	100.0	0.50	245.0
Rugby	105.2	0.50	235.6
Hazel	95.5	0.50	238.5
Copeland	107.0	1.0	238.0
Gore	107.2	0.50	476.2
Hiawassee	123.0	0.50	250.5
Martin*	101.0	0.50	255.0
Total	---	4.0	---

* Owned by Martin Company.
+ Refers to mean sea level U.S. Geodetic Survey data.

TABLE 111. ORLANDO WATER UTILITY GROUND STORAGE RESERVOIRS.

Location	Discharge elevation* (ft)	Capacity (mil gal)
Kirkman	99.1	2.0
Highland	87.0	3.5
Primrose	107.6	2.0
Pine Hills	112.5	2.0
Kuhl	98.4	2.0
Martin	102.0	1.0
Conway	108.0	2.0
Total	---	14.5

* Refers to mean sea level U.S. Geodetic Survey data.

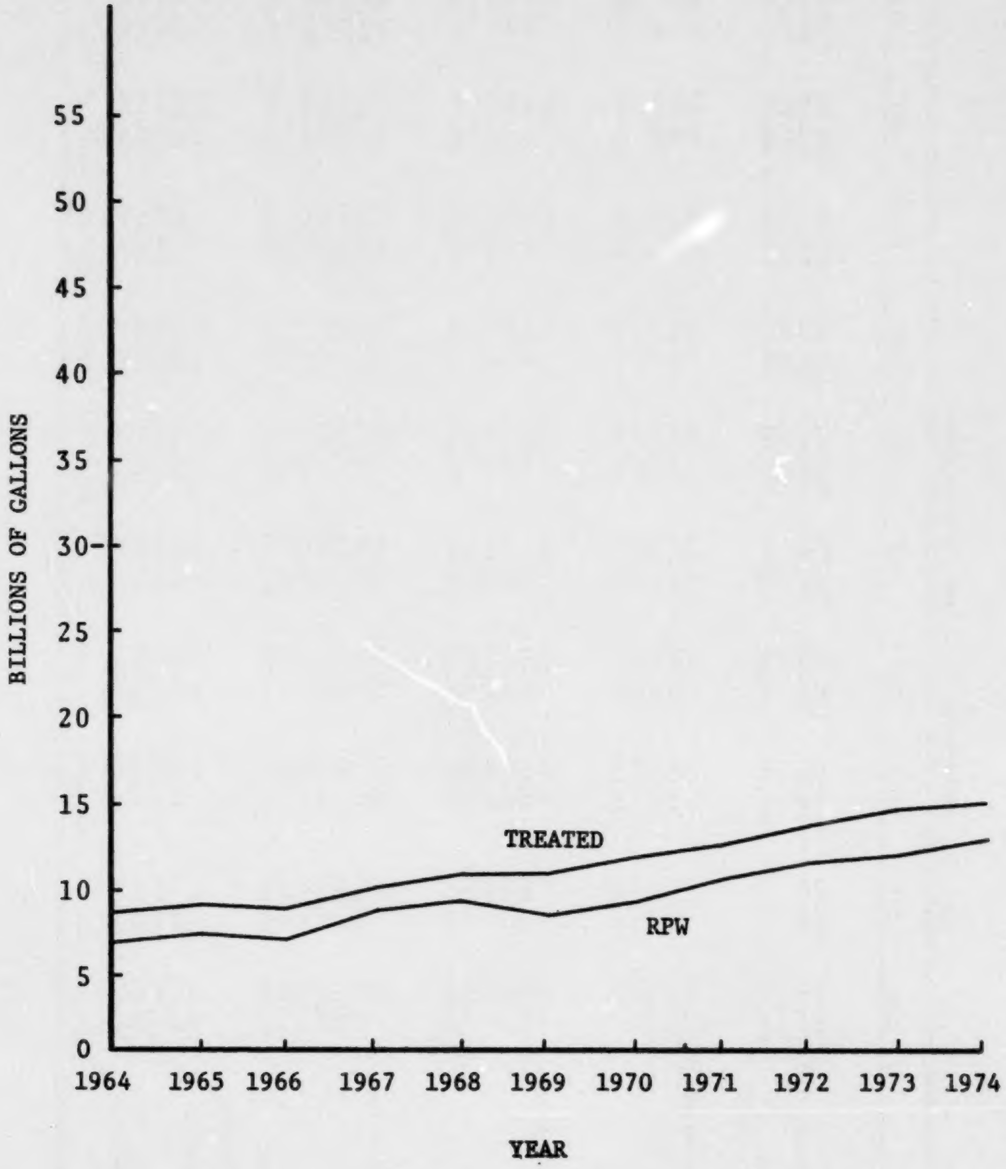


Figure 59. Orlando Water Utility water flow: treated water versus RPW.

TABLE 112. ORLANDO WATER UTILITY ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$208,855	$217,473	$266,481	$326,220	$344,976	$416,604	$402,293	$357,009	$445,506	$538,277
Accounting and collection	157,884	161,708	176,254	225,385	292,054	320,545	362,433	376,510	421,139	496,316
Other	---	---	---	---	---	111,144	116,846	125,150	135,053	161,002
Total support services	366,739	379,181	442,735	551,605	637,030	848,293	881,572	858,669	1,001,698	1,195,595
Acquisition:										
Operating supervision and engr	2,571	2,958	6,272	6,562	6,623	7,162	8,084	10,482	14,483	15,445
Other operating	20,103	21,595	23,188	24,463	25,203	26,626	29,052	31,717	56,447	58,063
Maintenance	13,132	15,332	17,984	19,814	27,486	33,458	52,536	57,131	48,255	49,170
Other	7,221	7,975	8,674	11,394	13,090	16,102	---	---	---	---
Total acquisition	43,027	47,860	56,118	62,233	72,402	83,348	89,672	99,330	119,185	122,679
Treatment:										
Operating supervision and engr	1,543	1,775	3,763	3,938	3,974	4,297	4,850	6,289	8,690	9,267
Chemicals	29,324	26,810	35,415	37,072	35,783	35,132	37,744	42,690	44,209	41,738
Other operating	12,062	12,957	13,912	14,678	15,122	15,976	17,431	19,030	33,868	34,838
Maintenance	7,880	9,199	10,790	11,889	16,492	20,075	31,522	34,279	28,953	29,502
Other	4,332	4,785	5,205	6,836	7,854	9,661	---	---	---	---
Total treatment	55,141	55,526	69,085	74,412	79,225	85,141	91,547	102,288	115,720	115,345
Power and pumping:										
Operating supervision and engr	6,171	7,100	15,053	15,750	15,896	17,189	19,401	25,158	34,758	37,069
Raw water power	29,758	25,670	38,360	35,717	38,373	44,551	112,712	139,509	149,597	208,096
Finished water power	88,663	82,914	102,894	88,542	92,259	122,859	137,383	170,511	182,841	248,160
Other operating	48,249	51,828	55,650	58,711	60,488	63,902	69,724	76,120	135,472	139,351
Maintenance	31,519	36,795	43,160	47,555	65,967	80,300	126,087	137,114	115,813	118,009
Other	17,330	19,141	20,819	27,345	31,417	38,645	---	---	---	---
Total power and pumping	221,690	223,418	275,936	273,620	304,400	367,446	465,307	548,412	618,481	750,691
Transmission and distribution:										
Supervision and engineering	39,302	43,913	60,735	80,471	91,666	100,459	111,869	7,078	61,105	102,561
Meters	81,190	84,132	87,581	93,058	95,398	97,077	103,761	108,352	122,551	153,531
Maintenance	137,086	167,555	145,634	145,309	149,440	190,497	185,843	256,950	297,280	302,723
Other	90,411	110,041	97,441	125,415	147,706	125,186	229,650	161,779	265,150	347,857
Total transmission and distr	347,989	405,641	391,391	44,253	484,210	513,219	631,123	534,159	746,086	906,672
Total	1,034,586	1,111,656	1,235,265	1,406,123	1,577,267	1,897,447	2,159,221	2,142,858	2,601,170	3,090,976

TABLE 113. ORLANDO WATER UTILITY UNIT OPERATING COSTS ($/mil gal RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support Services:										
Administration	$26.94	$30.15	$29.63	$33.86	$40.05	$43.52	$37.66	$31.38	$38.37	$42.99
Accounting and collection	20.36	22.42	19.59	23.40	33.91	33.48	33.93	33.09	36.27	39.64
Other	---	---	---	---	---	11.61	10.94	11.00	11.63	12.86
Total support services	47.30	52.56	49.22	57.28	73.96	88.59	82.53	75.47	86.28	95.48
Acquisition:										
Operating, supervision and engineering	0.33	0.41	0.70	0.68	0.77	0.75	0.76	0.92	1.25	1.23
Other operating	2.59	2.99	2.58	2.54	2.93	2.78	2.72	2.79	4.86	4.64
Maintenance	1.69	2.13	2.00	2.06	3.19	3.49	4.92	5.02	4.16	3.93
Other	0.93	1.11	0.96	1.18	1.52	1.68	---	---	---	---
Total acquisition	5.55	6.63	6.24	6.46	8.41	8.70	8.39	8.73	10.27	9.80
Treatment:										
Operating, supervision and engineering	0.20	0.25	0.42	0.41	0.46	0.45	0.45	0.55	0.75	0.74
Chemicals	3.78	3.72	3.94	3.85	4.15	3.67	3.53	3.75	3.81	3.33
Other operating	1.56	1.80	1.55	1.52	1.76	1.67	1.63	1.67	2.92	2.78
Maintenance	1.02	1.28	1.20	1.23	1.91	2.10	2.95	3.01	2.49	2.36
Other	0.56	0.66	0.58	0.71	0.91	1.01	---	---	---	---
Total treatment	7.11	7.70	7.68	7.73	9.20	8.89	8.57	8.99	9.97	9.21
Power and pumping										
Operating, supervision and engineering	0.80	0.98	1.67	1.64	1.85	1.80	1.82	2.21	2.99	2.96
Raw water power	3.84	3.56	4.26	3.71	4.46	4.65	10.55	12.26	12.89	16.62
Finished water power	11.43	11.49	11.44	9.19	10.71	12.83	12.86	14.99	15.75	19.82
Other operating	6.22	7.18	6.19	6.10	7.02	6.67	6.53	6.69	11.67	11.13
Maintenance	4.06	5.10	4.80	4.94	7.66	8.39	11.80	12.05	9.98	9.42
Other	2.23	2.65	2.31	2.84	3.65	4.04	---	---	---	---
Total power and pumping	28.59	30.97	30.68	28.41	35.34	38.38	43.56	48.20	53.27	59.95
Transmission and distribution										
Supervision and engineering	5.07	6.09	6.75	8.36	10.64	10.49	10.47	0.62	5.26	8.19
Meters	10.47	11.66	9.74	9.66	11.08	10.14	9.71	9.52	10.56	12.26
Maintenance	17.68	23.23	16.19	15.09	17.35	19.90	17.40	22.58	25.61	24.18
Other	11.66	15.25	10.83	13.02	17.15	13.07	21.50	14.22	22.84	27.78
Total transmission and distribution	44.88	56.23	43.51	46.13	56.22	53.60	59.08	46.95	64.26	72.41
Total	133.43	154.10	137.33	146.01	183.13	198.17	202.14	188.33	224.05	246.84

The above figures are not additive. They are obtained by dividing yearly mil gal RPW into the annual costs shown in the preceding table.

TABLE 114. ORLANDO WATER UTILITY OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	20.19	19.56	21.57	23.20	21.87	21.96	18.63	16.66	17.13	17.41
Accounting and collection	15.26	14.55	14.27	16.03	18.52	16.89	16.79	17.57	16.19	16.06
Other	---	---	---	---	---	5.86	5.41	5.84	5.19	5.21
Total support services	35.45	34.11	35.84	39.23	40.39	44.71	40.83	40.07	38.51	38.68
Acquisition:										
Operating, supervision and engineering	0.25	0.27	0.51	0.47	0.42	0.38	0.37	0.49	0.56	0.50
Other operating	1.94	1.94	1.88	1.74	1.60	1.40	1.35	1.48	2.17	1.88
Maintenance	1.27	1.38	1.46	1.41	1.74	1.76	2.43	2.67	1.[illegible]	1.59
Other	0.70	0.72	0.70	0.81	0.83	0.85	---	---	---	---
Total acquisition	4.16	4.31	4.54	4.43	4.59	4.39	4.15	4.64	4.59	3.97
Treatment										
Operating, supervision and engineering	0.15	0.16	0.30	0.28	0.25	0.23	0.22	0.29	0.33	0.30
Chemicals	2.83	2.41	2.87	2.64	2.27	1.85	1.75	1.99	1.70	1.35
Other operating	1.17	1.17	1.13	1.04	0.96	0.84	0.81	0.89	1.30	1.13
Maintenance	0.76	0.83	0.87	0.85	1.05	1.06	1.46	1.60	1.11	0.95
Other	0.42	0.43	0.42	0.49	0.50	0.51	---	---	---	---
Total treatment	5.33	4.99	5.59	5.29	5.03	4.49	4.24	4.77	4.44	3.73
Power and pumping										
Operating, supervision and engineering	0.60	0.64	1.22	1.12	1.01	0.90	0.90	1.17	1.34	1.20
Raw water power	2.88	2.31	3.11	2.54	2.43	2.35	5.22	6.51	5.75	6.73
Finished water power	8.56	7.46	8.33	6.30	5.85	6.47	6.36	7.96	7.03	8.03
Other operating	4.66	4.66	4.51	4.18	3.83	3.37	3.23	3.55	5.21	4.51
Maintenance	3.05	3.31	3.49	3.38	4.18	4.23	5.84	6.40	4.45	3.82
Other	1.68	1.72	1.69	1.94	1.99	2.04	---	---	---	---
Total power and pumping	21.43	20.10	22.35	19.46	19.30	19.36	21.55	25.59	23.78	24.29
Transmission and distribution										
Supervision and engineering	3.80	3.95	4.92	5.72	5.81	5.29	5.18	0.33	2.35	3.32
Meters	7.85	7.57	7.09	6.62	6.05	5.12	4.81	5.06	4.71	4.97
Maintenance	13.24	15.07	11.79	10.	9.47	10.04	8.61	11.99	11.43	9.79
Other	8.74	9.90	7.89	8.92	9.36	6.60	10.64	7.55	10.19	11.25
Total transmission and distribution	33.63	36.49	31.68	31.59	30.69	27.05	29.23	24.93	28.68	29.33
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 115. ORLANDO WATER UTILITY LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	535,664*	549,753	547,621*	600,879*	705,551*	779,012	846,319	1,214,955	1,464,267	1,571,133
Total hours on payroll	299,722	304,166	301,338	318,890	348,404	373,677	381,525	420,211	467,462	463,881
Revenue-producing water (mil gal)	7,754	7,214	8,995	9,630	8,613	9,575	10,682	11,378	11,610	12,522
Total payroll/mil gal RPW ($)	69.08	76.20	60.88	62.39	81.91	81.35	79.22	106.78	126.12	125.46
Total hours/mil gal RPW	38.65	42.16	33.50	33.11	40.45	39.02	35.71	36.93	40.26	37.04
Average cost/man-hour ($)	1.78	1.80	1.81	1.88	2.02	2.08	2.21	2.89	3.13	3.38

* Figures include overtime estimates.

TABLE 116. ORLANDO WATER UTILITY CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense	$1,034,586	$1,111,656	$1,235,265	$1,406,123	$1,577,267	$1,897,448	$2,159,220	$2,142,858	$2,601,170	$3,090,976
Depreciation	548,523	561,531	585,199	630,875	680,239	589,399	633,827	683,298	737,358	773,868
Interest*	475,513	447,280	409,968	407,447	396,729	393,518	617,578	923,338	926,271	1,065,954
Total	2,058,622	2,120,467	2,230,432	2,444,445	2,264,235	2,880,365	3,410,625	3,749,494	4,265,799	4,930,798
Total cost/mil gal RPW	265.49	293.94	247.96	253.83	308.18	300.82	319.28	329.53	367.44	393.77

* Calculated as 20% of total interest cost, including amortization, adjustments, and other interest costs.

TABLE 117. ORLANDO WATER UTILITY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	1,034,586	1,111,656	1,235,265	1,400,123	1,577,267	1,897,448	2,159,220	2,142,858	2,601,170	3,090,976
Capital expense ($)	1,024,036	1,008,311	995,167	1,038,322	1,076,968	982,917	1,251,405	1,606,627	1,664,629	1,839,822
Total ($)	2,058,622	2,120,467	2,230,432	2,444,445	2,654,235	2,880,365	3,410,625	3,749,494	4,265,799	4,930,798
Operating expense as % of total	50.26	52.43	55.38	57.52	59.42	65.88	63.31	57.15	60.98	62.69
Capital expense as % of total	49.74	47.57	44.62	42.48	40.58	34.12	36.69	42.85	39.02	37.31

components in the water delivery system. This section contains such an analysis of the water supply system costs.

Locations of the Orlando Water Utility facilities are shown in Figure 60. The dots represent the well fields along with the treatment and storage facilities. As shown, the Orlando Utility's system is simple and laid out so that no booster stations are required. Elevation of the storage facilities is shown in Table 110.

To analyze the cost of water as it moves through acquisition to treatment to the consumer, it is necessary to identify the capital and operating costs for each system component. Figure 61 is a schematic diagram of the functions of the Orlando utility and shows the operating and capital costs for each function. Each of the well fields is operated similarly. Low service pumping removes the water from the wells and moves it through the aeration and chlorination and into the ground reservoir storage. High service pumping moves the water into elevated storage and into the distribution system. Because the function of each well field is similar, the flow chart is representative of all well fields in the system.

The incremental cost of providing water to the distribution system is $101.35/mil gal. Added to the incremental cost are those for distribution, interest, and support services, as follows:

Costs:

Incremental cost ($/mil gal)	$101.35
Distribution cost ($/mil gal)	96.63
Interest ($/mil gal)	85.12
Support services cost ($/mil gal)	110.31
Total ($/mil gal)	393.41
Metered consumption (mil gal)	12,522.1
Revenue ($)	4,926,319.36

Distribution cost is calculated on the assumption that these unit costs are constant throughout the system. The total capital and operating cost for the distribution system is therefore divided by the number of gallons of RPW in the year under consideration, yielding a figure of $96.63/mil gal. The same approach is taken for interest and support services. When these costs are added, the total cost is $393.41/mil gal. This value multiplied by the annual metered consumption produces the total cost of water production for the year. Table 118 gives the current water rates.

Revenue-producing water for the 10 largest consumers served by the Orlando utility is shown in Table 119.

Locations of the major users in order of their consumption are shown in Figure 62. Because the water sources are well distributed, the cost of delivering water to each user is approximately the same.

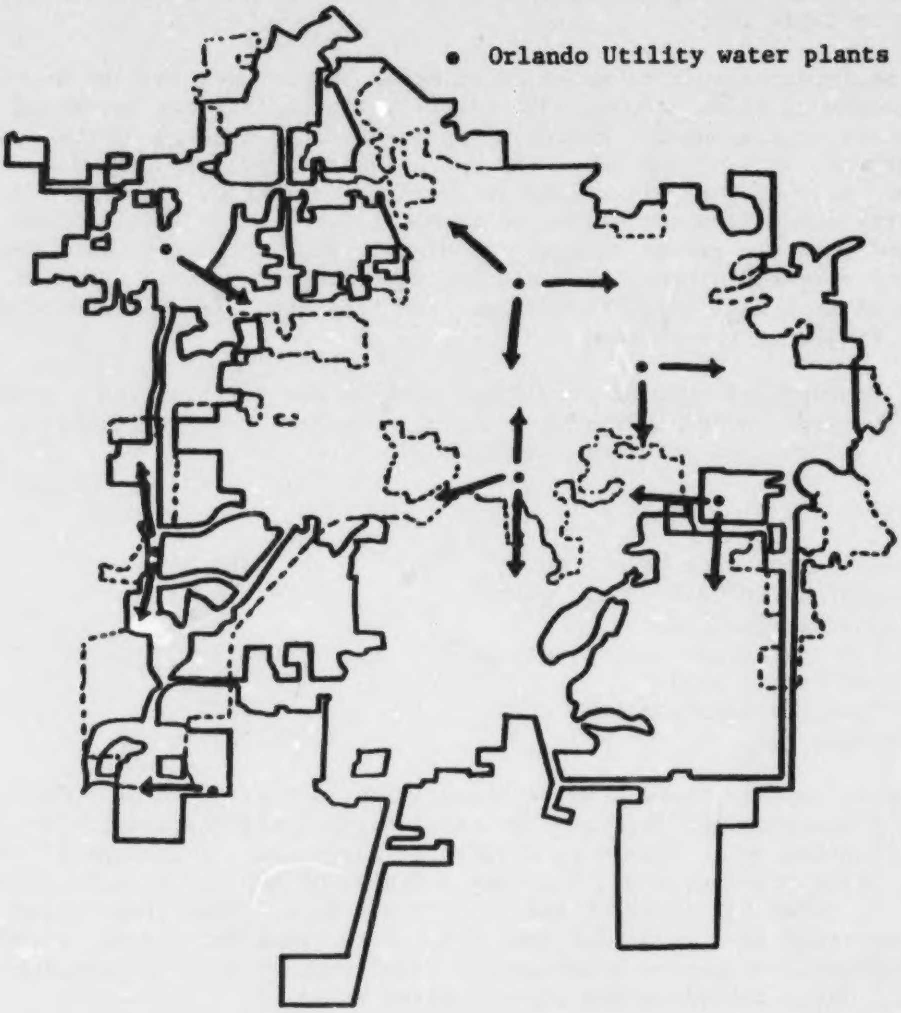
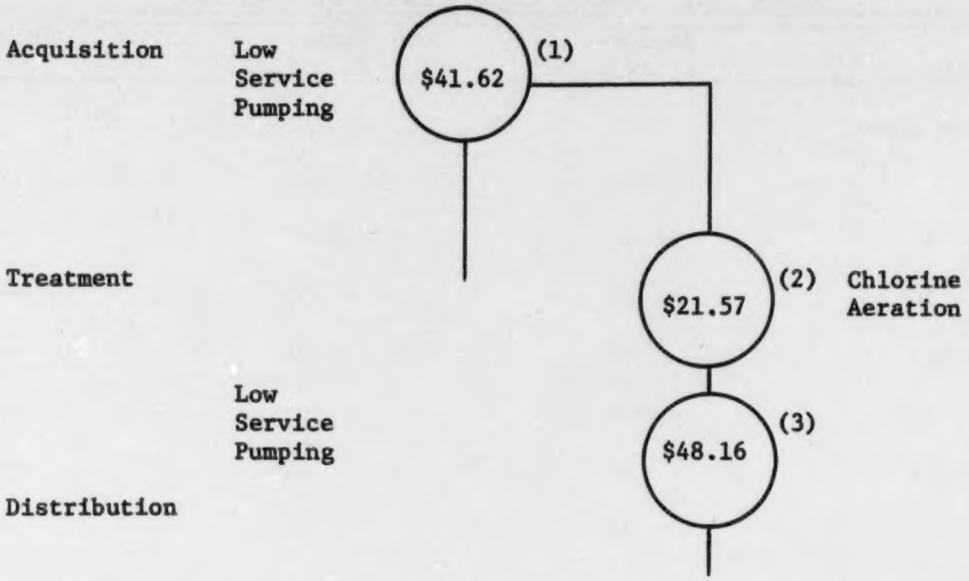

● Orlando Utility water plants

Figure 60. Orlando Water Utility flow map.


Acquisition
Low
Service
Pumping
$41.62
(1)
Treatment
$21.57
(2)
Chlorine
Aeration
Low
Service
Pumping
$48.16
(3)
Distribution

(1) Includes power and depreciation + $15/mil gal unidentifiable O&M expenses.

(2) Includes chemical and depreciation = $9.09/mil gal unidentifiable O&M expenses.

(3) Includes power and depreciation + $15/mil gal unidentifiable O&M expenses.

Figure 61. Orlando Water Utility allocation of capital and operating expenses to water system components ($/mil gal RPW).

TABLE 118. ORLANDO WATER UTILITY WATER RATES.

Blocks	January 1, 1974	January 1, 1975	July 1, 1975
Inside city:			
0 - 1	---	---	$1.85
0 - 4	$2.60	$2.67	---
5 - 10	.33	.35	---
11-50	.32	.35	---
2 - 100	---	---	.41
51-100	.29	.35	---
101 +	.21	.25	.31
Outside city:			
0 - 1	---	---	2.54
0 - 4	3.57	3.67	---
5 - 10	.45	.48	---
11 - 50	.44	.48	---
2 - 100	---	---	.56
51 - 100	.39	.48	---
101 +	.38	.34	.42

TABLE 119. ORLANDO WATER UTILITY RPW OF 10 MAJOR USERS

Major user	High or low date	Date	Units used (mil gal)	Amount billed	Unit charge ($/MG) With tax	Unit charge ($/MG) Without tax	Cost zone
Navy	High	Oct 74	49.6	$10,432.46	---	$210.21	1
	Low	Mar 75	37.6	9,409.27	---	250.30	
Martin	High	Jan 75	38.1	3,816.80	---	100.21*	1
	Low	Jun 75	28.5	2,860.00	---	100.28*	
Coca Cola	High	Jun 75	7.1	1,785.27	$107.41	251.16*	1
	Low	Jan 75	3.0	772.02	66.88	253.70*	
Habitat	High	Apr 75	2.1	540.02	54.00	255.33	1
	Low	Oct 74	0.4	95.84	9.58	236.06	
Florida Hospital	High	Nov 74	5.0	1,068.56	78.74	212.10	1
	Low	Sep 75	2.5	776.21	67.05	314.67	
American Bakeries	High	Jun 75	5.9	1,491.02	408.48	251.90*	1
	Low	Jan 75	4.1	1,041.53	331.51	252.73*	
Frito Lay	High	Aug 75	9.0	2,788.11	147.52	311.28*	1
	Low	Oct 75	5.7	1,765.11	106.60	312.02*	
Royal Crown	High	Oct 74	8.9	1,879.58	255.59	211.19	1
	Low	Apr 75	3.6	906.27	205.40	253.15	
Orange Memorial	High	Oct 74	6.7	1,411.49	92.46	211.59*	1
	Low	Dec 74	4.1	862.13	70.49	212.86*	
Sheraton Olympic	High	Aug 75	6.8	2,879.96	---	422.34	1
	Low	Feb 75	0.7	237.09	---	364.19	

* Rate increases occurred January 1, 1975 and July 1, 1975.

1 USN Training Center
2 Martin Company
3 Coca Cola Company
4 Habitat Apartments
5 Florida Hospital
6 Park Plaza Hotal
7 Frito Lay, Inc.
8 Royal Crown Cola
9 Orange Memorial Hospital
10 Sheraton Olympic Hotel

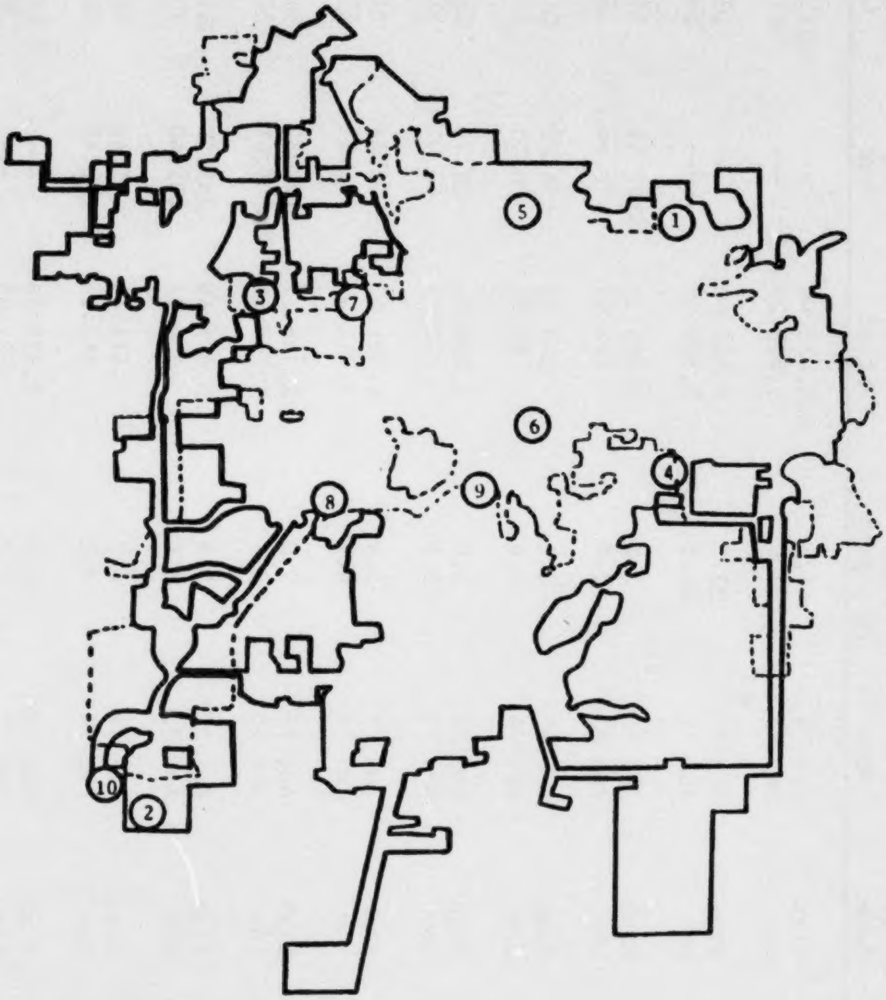


Figure 62. Orlando Water Utility major users.

The average unit costs for all water supplied during the most recent year studied are given as follows:

	$/mil gal
Support services	110
Acquisition	42
Treatment	22
Distribution	135
Interest	85
Total	394

SECTION 14

ELIZABETHTOWN WATER COMPANY

The Elizabethtown Water Company provides treated water to areas in five counties of New Jersey, with a combined population of 1.8 million--Union, Middlesex, Summerset, Mercer, and Hunterdon. The retail service area of the Elizabethtown Water Company includes a relatively stable population of 507,836 as of 1974. The amount of water consumed increased by 30% over the 10-year period of the study, primarily as a result of integrating smaller utilities.

As an investor-owned utility, the Elizabethtown Water Company has some different characteristics from the majority of utilities studied; for example, unlike publicly owned utilities, an investor-owned utility incurs liability for real estate taxes. Tables 120 and 121 show some basic system facts.

WATER SUPPLY SERVICE AREA

The Elizabethtown Water Company provides water on a wholesale and retail basis to all classes of customers within the service area (Figure 63). The service area includes irregularly shaped portions of the five counties listed above. In addition, treated water is sold on a wholesale basis to York, Elizabeth, and other cities, and to other water companies such as Commonwealth Water Company and Middlesex Water Company. Service to these large customers is provided through master meters.

Limited amounts of treated water are purchased from other utilities, primarily the Newark Utility, located at the northeast end of the company's operating area.

ORGANIZATION

The Elizabethtown Water Company is controlled by a board of directors headed by a chairman to whom the president of the company reports. As shown in Figure 64, the president has four organizational areas reporting to him--operations, controller, business, and legal. The largest area, operations, includes engineering, planning, and the physical operations and maintenance of the entire utility. The controller's area is responsible for all financial documentation and accounting of the activities as well as meter reading, billing, and collecting. The business area handles purchasing, contracting, and personnel records.

TABLE 120. ELIZABETHTOWN WATER COMPANY, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	N.A.
County (Union, Middlesex, Summerset, Mercer, Hunterdon)	1,800,000
Retail service area	507,836
Area of retail service area (sq miles)	440
Recognized customer classes (no. of meters by meter size shown in Table 121)	
Percent metered	100
Purchased water (mil gal)	
Treated	95
Raw	32,597
Source water:	
Surface (%)	77
Wells (%)	23
Pipe in system (miles)	1,790
Elevation of treatment plants (ft above mean sea level):	
Somerville	60
Raritan-Millstone	40
Pottersville	460
Stony Brook	98
Harrison Station	65
Elevation of service area (min-max ft)	0 - 560
Revenue producing water (mil gal)	38,235
Treated water (pumpage from treatment plants + treated purchased water, mil gal)	43,886
Maximum day/maximum hour (MGD)	157/226

TABLE 121. ELIZABETHTOWN WATER COMPANY NUMBER OF METERS BY METER SIZE

Meter size (in.)	No. of meters
5/8	117,007
3/4	3,621
1	2,521
1½	1,073
2	1,204
3	338
4	465
6	708
8	201
10	25
12	4
16	1
20	1

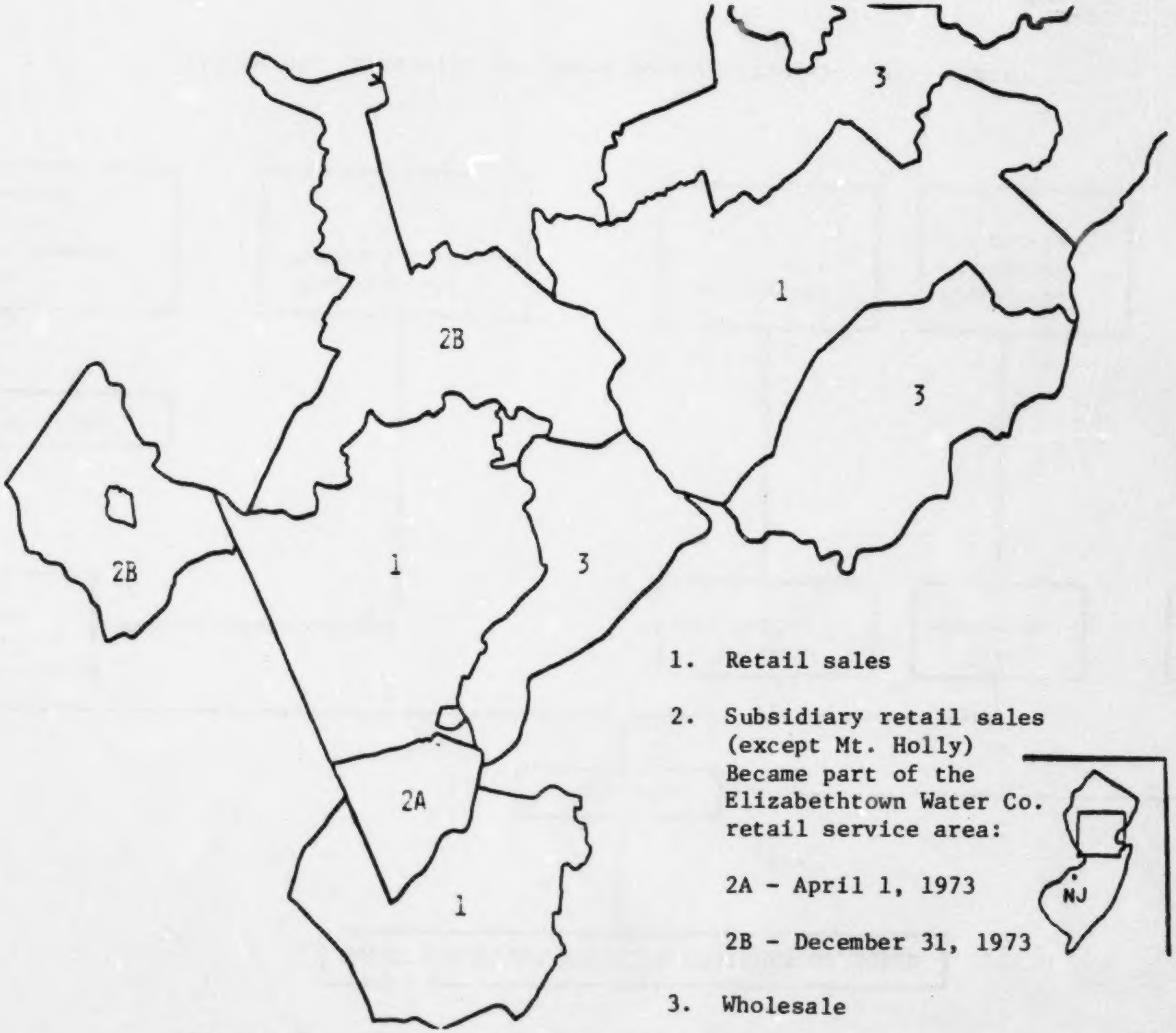

3
1
2B
3
2B
1
3
2A
1
NJ
1. Retail sales
2. Subsidiary retail sales (except Mt. Holly) Became part of the Elizabethtown Water Co. retail service area:
2A - April 1, 1973
2B - December 31, 1973
3. Wholesale

Figure 63. Elizabethtown Water Company service area map.

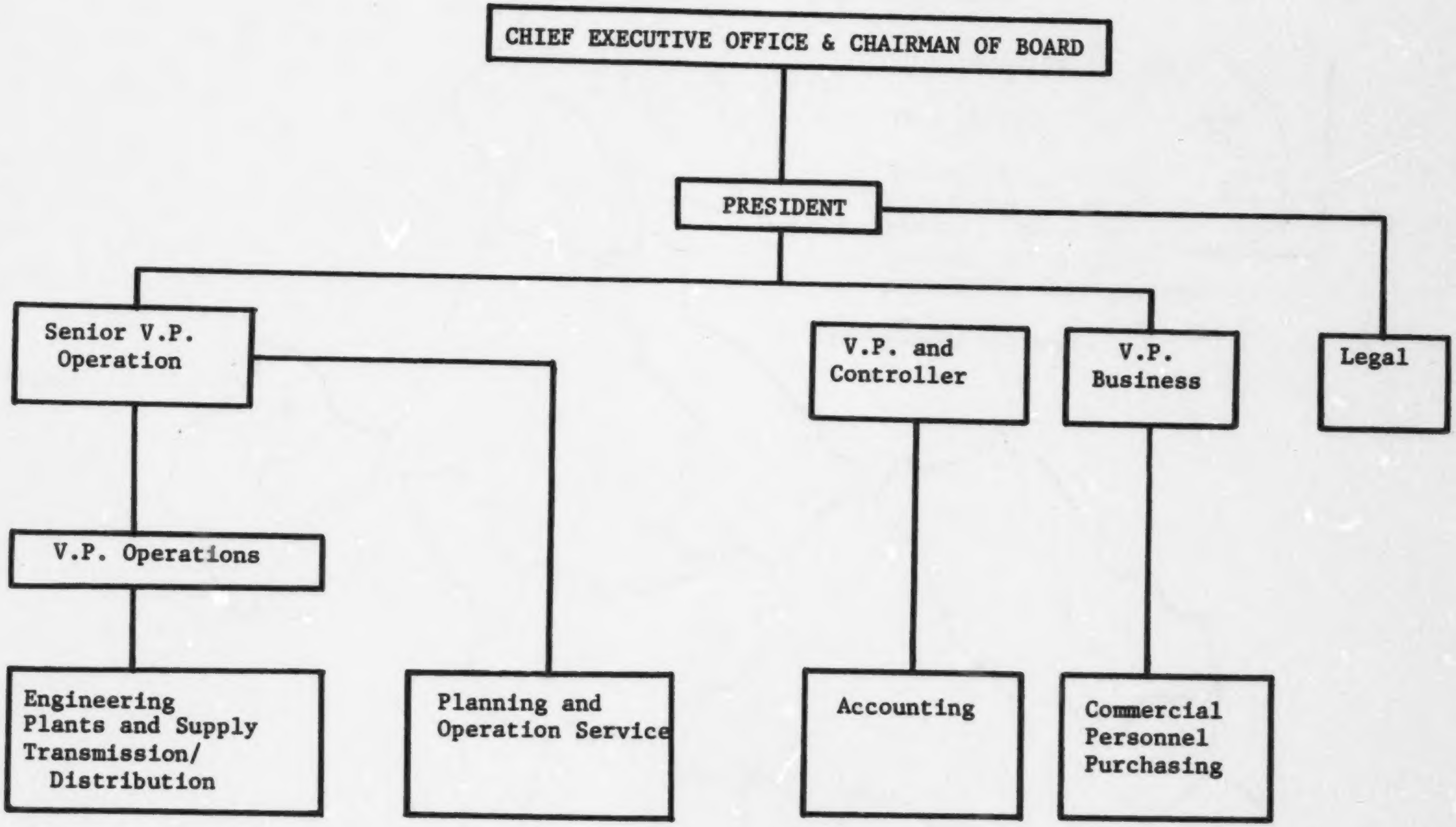

CHIEF EXECUTIVE OFFICE & CHAIRMAN OF BOARD
PRESIDENT
Senior V.P. Operation
V.P. and Controller
V.P. Business
Legal
V.P. Operations
Engineering Plants and Supply Transmission/ Distribution
Planning and Operation Service
Accounting
Commercial Personnel Purchasing

Figure 64. Elizabethtown Water Company organizational chart.

ACQUISITION

Raw water comes from both surface and ground sources--approximately 77% surface and 23% ground. Payments made to the State of New Jersey for surface water are designed to cover the proportional share of the cost for operating and financing the Spruce Run and Round River reservoirs, which are the primary sources of water. The company has grants to obtain 70 MGD from the Raritan River Basin, with an option to go up to 110 MGD to meet peaks in demand. Other grants permit withdrawal of 28 MGD from the Delaware River via the Delaware and Raritan Canal and nearly three MGD from the Raritan River. In addition to this surface water, the company obtains another 40 MGD from wells located at various points throughout the service area. The surface water is processed through four treatment plants that purify the water and deliver it to the distribution system. Additional water is added in the distribution system from well fields located at various points within the distribution system. The well water is chlorinated and moved directly into the distribution system along with the water from the treatment facilities.

TREATMENT

Raw surface water is treated at four facilities: Harrison Street Station, Raritan Millstone Filter Plant (Figure 65), Somerville Filter Plant, and Potterville Plant. At one time, these facilities were part of independent utility systems that were brought together to form the Elizabethtown Water Company. The facilities were constructed at different times and provide water to different zones of the service area. Each facility has an intake at a river or canal that flows by or near the filter plant. The plants are similar in operation and have coagulation basins for sedimentation and flocculation.

At times, taste and odor problems have occurred as a result of winter thaws followed by heavy rainstorms. In such situations, the run-off into the watershed contains road tars, oil, salt, fertilizer, etc. These instances are predictable, and the facility treatment process is capable of making the water supply entirely safe to drink despite its potability. There are times, however, when such water has a medical or chemical taste or odor. This is a recurring problem, and some progress has been made in overcoming it. The technology of the industry has not reached the state where taste and odor problems can be completely eliminated.

The main treatment plant, Raritan Millstone, has a capacity of 160 MGD. The other three plants are significantly smaller, with the Somerville filter plant having a capacity of 8.0 MGD, Stoneybrook plant, 6.0 MGD, and Potterville plant, 0.5 MGD. This gives a combined surface water treatment capability of 174.5 MGD.

Chlorination is accomplished at all well sites, and one well site where there are eight wells operates a 2.0 MGD treatment facility for iron removal.

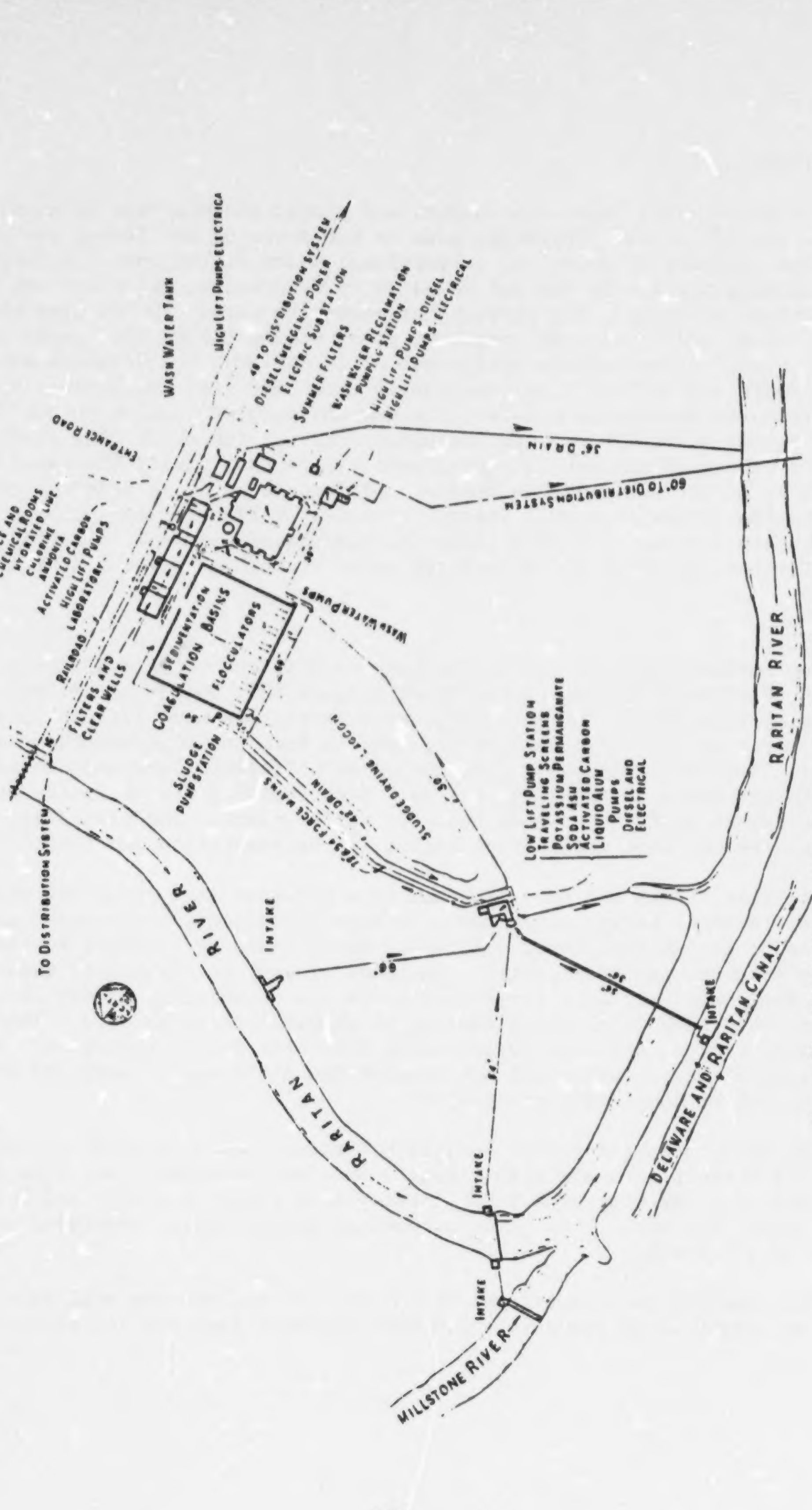

Wash Water Tank
High Lift Pumps Electrica
48" to Distribution System
Diesel Emergency Power
Electric Substation
Summer Filters
Wash Water Reclamation
Pumping Station
High Lift Pumps - Diesel
High Lift Pumps - Electrical
Entrance Road
Offices and
Chemical Rooms
Hydrated Lime
Chlorine
Ammonia
Activated Carbon
High Lift Pumps
Laboratory
Railroad
Filters and
Clear Wells
Coagulation
Sedimentation Basins
Flocculators
Wash Water Pumps
36" Drain
60" To Distribution System
Sludge
Pump Station
Sludge Drying Lagoon
42" Drain
Force Mains
Low Lift Pump Station
Traveling Screens
Potassium Permanganate
Soda Ash
Activated Carbon
Liquid Alum
Pumps
Diesel and
Electrical
To Distribution System
Raritan River
Intake
60"
36"
54"
Intake
Intake
Intake
Millstone River
Delaware and Raritan Canal
Raritan River

Figure 65. Elizabethtown Water Company, Raritan-Millstone Plant.

TRANSMISSION AND DISTRIBUTION

The transmission and distribution system is relatively complex. Thirty-nine well fields consisting of approximately 100 wells each inject water into the system at various points. In addition, 30 booster stations operate one to six pumps each. Also intermixed in the distribution system are seven storage reservoirs with a combined capacity of 14.2 mil gal, one clear well with a 0.1-mil gal capacity, 17 storage tanks with a combined capacity of 38.9 mil gal, and seven standpipes with a combined capacity of 4.1 mil gal. Table 122 provides information on the system's storage.

The transmission and distribution system consists of approximately 1,790 miles of underground pipe ranging from 60 in. in diameter at the main treatment facility to the 2-in. pipe used in portions of the system. Transmission of large amounts of water throughout the entire system is somewhat reduced by the location of the wells.

COST ANALYSIS

Growth in consumer demand for water from 1964 through 1974 is shown in Figure 66.

Using the standard cost categories, data were collected and reported as shown in Tables 123, 124, and 125. As indicated by the relative increase in the support services category, a major portion of the operating budget was expended for labor. Table 126 examines labor costs of operations and maintenance activities related to producing water. As shown, the cost/man-hour increased by 73%, whereas the total payroll hours required to produce 1 mil gal of RPW decreased by 10%. This means that the operating costs for producing water did not increace as rapidly as the labor costs/man-hour. When it is no longer possible to gain increasing efficiency with respect to manpower, the payroll cost will start to increase at least at the same rate as labor cost.

Table 127 summarizes the operating, depreciation, and interest expenses for the 10-year period. Table 128 computes the capital and operating expenditure ratios. Operating expenses are shown as a total of the values in Table 123, which represent expenses incurred in the norman day-to-day operation of the system. The capital expenses are the total of periodic expenditures to provide major equipment and facilities plus the interest charged on money borrowed for these purposes.

A comparison of the operating and capital expenses as a percent of total (Table 127) shows more expenses associated with operations than with capital. Over the 10-year period, the trend remained in favor of operation; however, the ratio has shifted somewhat toward capital. In 1965, the ratio was approximately 76% operating expense to 24% capital expense. In 1974, the ratio had changed to the point that only 69% was expended for operations, and 31% was expended for capital.

TABLE 122. ELIZABETHTOWN WATER COMPANY STORAGE FACILITIES

Type of storage	Ground elevation (ft)	Overflow Elevation (ft)	Capacity (mil gal)
Storage reservoirs:			
Netherwood	120	133	0.5
Netherwood	120	133	1.0
Jerusalem	243	264	9.4
Springfield	106	116	1.0
Hummocks	61	71	1.0
Stony Brook	---	---	0.3
Harrison St.	---	---	1.0
Collecting reservoir:			
Pottersville	---	488	6.5
Clear well:			
Pottersville	---	---	0.1
Tanks:			
Oak Tree	156	216	10.0
Oak Tree	156	216	10.0
Johnson Drive	239	264	0.8
Johnson Drive	487	579	0.5
Michigan Ave.	171	276	2.0
Coles Ave.	515	560	0.2
Jerusalem	265	365	1.5
Warren Twp.	575	639	0.5
Hi Thor	540	645	0.4
Hummocks	72	283	0.3
Montgomery	153	273	1.0
Mtnside	545	633	0.4
John St.	200	319	0.6
Terhune	222	319	0.6
Salzman	311	400	0.1
Oak Tree	160	216	5.0
Hummocks	40	95	5.0
Standpipes:			
Drakes Corner	397	437	0.1
Raritan	56	206	0.6
Bridgewater	168	264	0.4
Branchburg	223	319	1.0
Washington Valley	635	711	1.0
Oak Tree	156	252	0.9
Drakes Corner	397	437	0.1

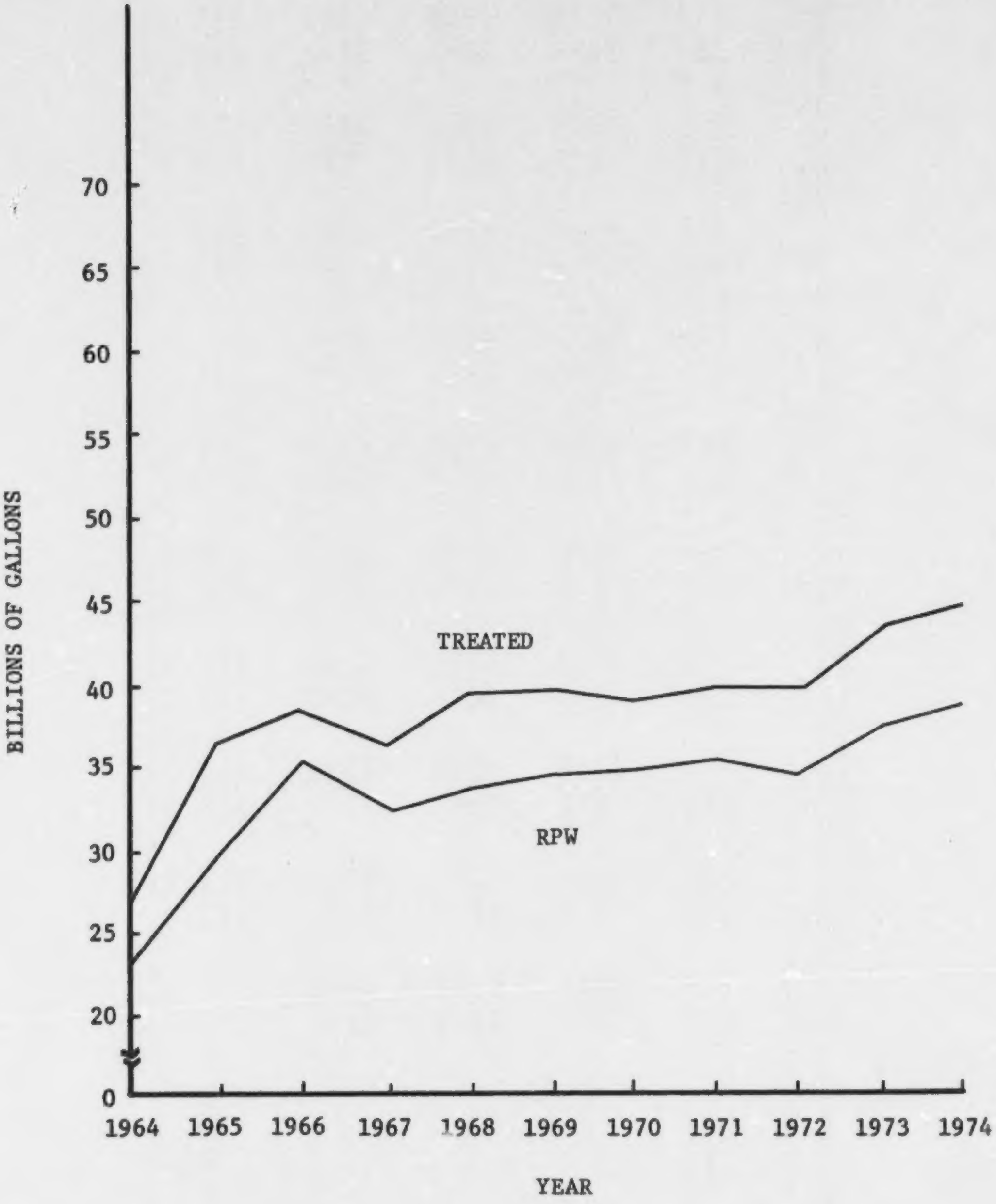


Figure 66. Elizabethtown Water Company water flow: treated water versus RPW.

TABLE 123. ELIZABETHTOWN WATER COMPANY ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$820,203	939,772	$990,793	$1,050,742	$1,275,119	$1,509,030	$1,664,239	$1,693,288	$1,977,604	$2,138,306
Accounting and collection	371,476	365,564	401,178	448,651	491,310	598,985	612,352	658,040	699,221	889,422
Total support services	1,191,679	1,305,336	1,391,971	1,449,393	1,766,429	2,108,015	2,276,591	2,351,328	2,676,825	3,027,728
Acquisition:										
Operating	8,483	7,407	7,680	10,479	6,658	7,046	5,139	5,134	5,278	8,329
Purchased water	447,048	704,860	928,782	958,190	1,026,094	1,085,668	1,129,825	1,444,576	1,441,516	1,442,434
Maintenance	29,332	35,971	42,918	79,631	60,033	82,502	91,033	42,685	31,394	50,760
Total acquisition	484,863	748,238	979,380	1,048,300	1,092,785	1,175,216	1,225,997	1,492,395	1,478,188	1,501,523
Treatment:										
Operating	109,723	110,123	129,198	110,497	108,164	118,694	145,918	189,167	177,853	373,034
Chemicals	294,027	389,575	258,805	354,328	400,771	380,955	432,830	426,643	490,264	603,167
Maintenance	43,852	64,879	24,466	53,681	70,295	93,810	112,424	109,094	121,440	139,305
Total treatment	447,602	564,577	412,469	518,506	579,230	593,459	691,172	724,904	789,557	1,115,506
Power and pumping:										
Operating	236,619	234,696	264,624	287,392	286,089	272,731	317,638	232,290	376,934	327,343
Fuel and power	667,728	784,544	723,653	756,166	820,809	797,880	1,045,675	1,066,204	1,272,486	2,198,957
Maintenance	59,833	60,217	54,292	60,843	54,476	60,905	45,016	113,969	169,414	184,113
Total power and pumping	964,180	1,079,447	1,042,569	1,104,401	1,161,374	1,131,516	1,408,329	1,412,463	1,818,834	2,710,413
Transmission and distribution:										
Operating	388,579	444,813	495,101	599,825	665,548	719,317	801,718	739,116	745,037	930,208
Maintenance	230,458	198,974	207,403	212,965	213,672	198,979	215,457	280,459	323,877	363,784
Total transmission and distr.	619,037	643,787	702,504	812,790	879,220	918,296	1,017,175	1,019,575	1,068,914	1,293,992
Total	3,707,361	4,341,385	4,528,893	4,983,390	5,479,038	5,926,502	6,619,264	7,000,665	7,832,318	9,649,162

TABLE 124. ELIZABETHTOWN WATER COMPANY UNIT OPERATING COSTS ($/mil gal RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$27.95	$27.19	$31.24	$31.61	$37.66	$43.85	$47.79	$49.38	$54.07	$55.92
Accounting and collection	12.66	10.58	12.65	13.50	14.51	17.41	17.59	19.19	19.12	23.26
Total support services	40.61	37.77	43.89	45.11	52.17	61.26	65.38	68.57	73.19	79.18
Acquisition:										
Operating	0.29	0.21	0.24	0.32	0.20	0.20	0.15	0.15	0.14	0.22
Purchased water	15.23	20.39	29.29	28.83	30.30	31.55	32.45	42.13	39.42	37.73
Maintenance	1.00	1.04	1.35	2.40	1.77	2.40	2.61	1.24	0.86	1.33
Total acquisition	16.52	21.64	30.88	31.55	32.27	34.15	35.21	43.52	40.42	39.28
Treatment:										
Operating	3.74	3.19	4.07	3.32	3.19	3.45	4.19	5.52	4.86	9.76
Chemicals	10.02	11.27	8.16	10.66	11.84	11.07	12.43	12.44	13.41	15.78
Maintenance	1.49	1.88	0.77	1.62	2.08	2.73	3.23	3.18	3.32	3.64
Total treatment	15.25	16.34	13.00	15.60	17.11	17.25	19.85	21.14	21.59	29.18
Power and pumping:										
Operating	8.06	6.79	8.34	8.65	8.45	7.93	9.12	6.77	10.31	8.56
Fuel and power	22.75	22.70	22.82	22.75	24.24	23.19	30.03	31.09	34.79	57.51
Maintenance	2.04	1.74	1.71	1.83	1.61	1.77	1.29	3.32	4.63	4.82
Total power and pumping	32.85	31.23	32.87	33.23	34.30	32.89	40.44	41.18	49.73	70.89
Transmission and distribution:										
Operating	13.24	12.87	15.61	18.05	19.65	20.90	23.02	21.55	20.37	24.33
Maintenance	7.85	5.76	6.54	6.41	6.31	5.78	6.19	8.18	8.86	9.51
Total transmission and distribution	21.09	18.63	22.15	24.46	25.96	26.68	29.21	29.73	29.23	33.84
Total operating cost	126.32	125.61	142.79	149.95	161.81	172.23	190.09	204.14	214.16	252.37

TABLE 125. ELIZABETHTOWN WATER COMPANY OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	22.13	21.65	21.88	21.08	23.27	25.46	25.14	24.19	25.25	22.16
Accounting and collection	10.02	8.42	8.86	9.00	8.97	10.11	9.25	9.40	8.93	9.22
Total support services	32.15	30.07	30.74	30.08	32.24	35.57	34.39	33.59	34.18	31.38
Acquisition:										
Operating	0.23	0.17	0.17	0.21	0.12	0.12	0.08	0.07	0.07	0.09
Purchased water	12.06	16.23	20.51	19.24	18.73	18.32	17.07	20.64	18.41	14.94
Maintenance	0.79	0.83	0.95	1.60	1.09	1.39	1.37	0.61	0.40	0.53
Total acquisition	13.08	17.23	21.63	21.05	19.94	19.83	18.52	21.32	18.88	15.56
Treatment:										
Operating	2.96	2.54	2.85	2.21	1.97	2.00	2.20	2.70	2.27	3.87
Chemicals	7.93	8.97	5.71	7.11	7.32	6.43	6.54	6.09	6.26	6.25
Maintenance	1.18	1.50	0.54	1.08	1.29	1.59	1.70	1.56	1.55	1.44
Total treatment	12.07	13.01	9.10	10.40	10.58	10.02	10.44	10.35	10.08	11.56
Power and pumping										
Operating	6.38	5.41	5.84	5.77	5.22	4.60	4.80	3.32	4.81	3.39
Fuel and power	18.01	18.06	15.98	15.17	14.99	13.46	15.80	15.23	16.24	22.79
Maintenance	1.61	1.39	1.20	1.22	0.99	1.03	0.68	1.63	2.16	1.91
Total power and pumping	26.00	24.86	23.02	22.16	21.20	19.09	21.28	20.18	23.21	28.09
Transmission and distribution:										
Operating	10.49	10.24	10.93	12.04	12.14	12.13	12.11	10.55	9.51	9.64
Maintenance	6.21	4.59	4.58	4.27	3.90	3.36	3.26	4.01	4.14	3.77
Total transmission and distribution	16.70	14.83	15.51	16.31	16.04	15.49	15.37	14.56	13.65	13.41
Total operating expense	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABEL 126. ELIZABETHTOWN WATER COMPANY LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	1,587,811	1,654,576	1,722,878	1,846,771	2,063,137	2,158,699	2,421,262	2,492,084	2,720,899	3,206,656
Total hours on payroll*	430,560	501,28	486,720	488,800	465,920	476,320	468,000	461,760	480,480	503,360
Revenue-producing water (mil gal)	29,349	34,565	31,711	33,236	33,862	34,410	34,822	34,291	36,572	38,235
Total payroll/mil gal ($)	54.10	47.87	54.33	58.24	60.93	62.73	69.53	72.67	74.40	83.87
Total hours/mil gal	14.67	14.50	15.35	15.41	13.76	13.84	13.44	13.47	13.14	13.16
Average cost/man-hour ($)	3.69	3.30	3.54	3.78	4.43	4.53	5.17	5.40	5.66	6.37

* Calculated (2080 x average number of employees).

TABLE 127. ELIZABETHTOWN WATER COMPANY CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense	$3,707,361	$4,341,385	$4,528,893	$4,983,390	$5,479,038	$5,926,502	$6,619,264	$7,000,665	$7,832,318	$9,649,165
Depreciation	915,402	1,004,132	1,078,670	1,145,037	1,199,771	1,296,594	1,351,526	1,418,022	1,520,845	1,692,842
Other:										
Interest	1,039,159	1,344,648	1,577,222	1,872,357	2,058,123	2,926,501	2,819,429	2,907,539	3,373,375	4,326,732
Taxes	2,646,337	2,658,194	2,323,726	2,558,779	3,561,304	3,391,773	3,210,237	3,030,096	4,616,579	3,935,124
Total capital and operating cost	8,308,259	9,348,359	9,508,511	10,559,563	12,748,236	13,541,370	14,000,456	14,356,322	17,343,117	19,603,863
Total cost/mil gal RPW	283.08	270.45	299.85	317.71	376.48	393.53	402.05	418.66	474.21	512.71

TABLE 128. ELIZABETHTOWN WATER COMPANY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expenses ($)	6,353,698	6,999,579	6,852,619	7,542,169	9,040,342	9,318,275	9,829,501	10,030,761	12,448,897	13,584,289
Taxes	(2,646,337)	(2,658,194)	(2,323,726)	(2,558,779)	(3,561,304)	(3,391,733)	(3,210,237)	(3,030,096)	(4,616,579)	(3,935,124)
Capital expenses ($)	1,954,561	2,348,780	2,655,892	3,017,394	3,707,894	4,223,095	4,170,955	4,325,561	4,894,220	6,019,574
Total expense ($)	8,308,259	9,348,359	9,508,511	10,559,563	12,748,236	13,541,370	14,000,456	14,356,322	17,343,117	19,603,863
Operating expense as % of total	76.47	74.87	72.07	71.43	70.91	68.81	70.29	69.87	71,78	69.29
Capital expense as % of total	23.53	25.13	27.93	28.57	29.09	31.19	29.70	30.13	28.22	30.71

The Elizabethtown system is relatively old; therefore, the capital depreciated was expended when costs were significantly lower than at present. On the other hand, the operating expense is in current dollars. This ratio will change whenever capital investments are made by the utility, and the change will generally be proportional to the significance of the investment. For example, if a new treatment facility is added, the ratio of capital to operating expense will significantly increase because of the impact of the depreciated capital of the new investment.

SYSTEM COSTS

Examination of the costs on a functional basis is only part of the total cost picture. Because the purpose of a water supply utility is to deliver water to a consumer, it is important to be able to present costs as they relate water delivery to a demand point within the distribution system. For this reason, the functional categories, both operating and capital, will be reaggregated and assigned to physical components in the delivery system. This section contains such an analysis of the water supply system's cost.

Locations of the Elizabethtown Water Company facilities are shows in Figure 67. Because the locations of the 39 well fields and the 30 booster stations make it extremely difficult to identify a specific flow pattern, no arrows are drawn to show the general flow of water. Careful examination must be made of the figure to determine the locations of the wells and booster stations. Booster stations and wells are too numerous to list.

To analyze the Elizabethtown utility on a physical functions basis, it is necessary to make some basic assumptions. Costs associated with individual wells and booster stations are generally available from the utility and can be identified to the level of the function. Also, the water company, in general terms, operates four independent systems rather than one joint system with four treatment plants; well fields can be identified as located in the general distribution area of a specific treatment plant. Booster facilities and their costs can also be identified in general terms to be associated with water from specific well fields or from specific treatment plants.

Determining whether water has been boosted once, twice, three times, or more is extremely difficult, however. For the purpose of this analysis, all water that has been boosted, regardless of the number of times, is placed in one category, and all water that has not been boosted except as it was pumped from the treatment plant or from the wells is considered in another category. Based on this assumption, and lumping all costs of boosting into a single booster category, it is possible to analyze the system.

Figure 68 is a simplified schematic representation of this complicated system, using the assumption outlined above. By using one of the systems as an example, the figure is better understood. System S_1 is the Raritan Millstone filter plant. The first block shows the cost of the river source as \$59.52/mil gal; moving down to the next block, treatment is shown as \$42.07/mil gal; then \$39.44/mil gal is added to pump the treated water from the treatment facility into the transmission and distribution system. Water

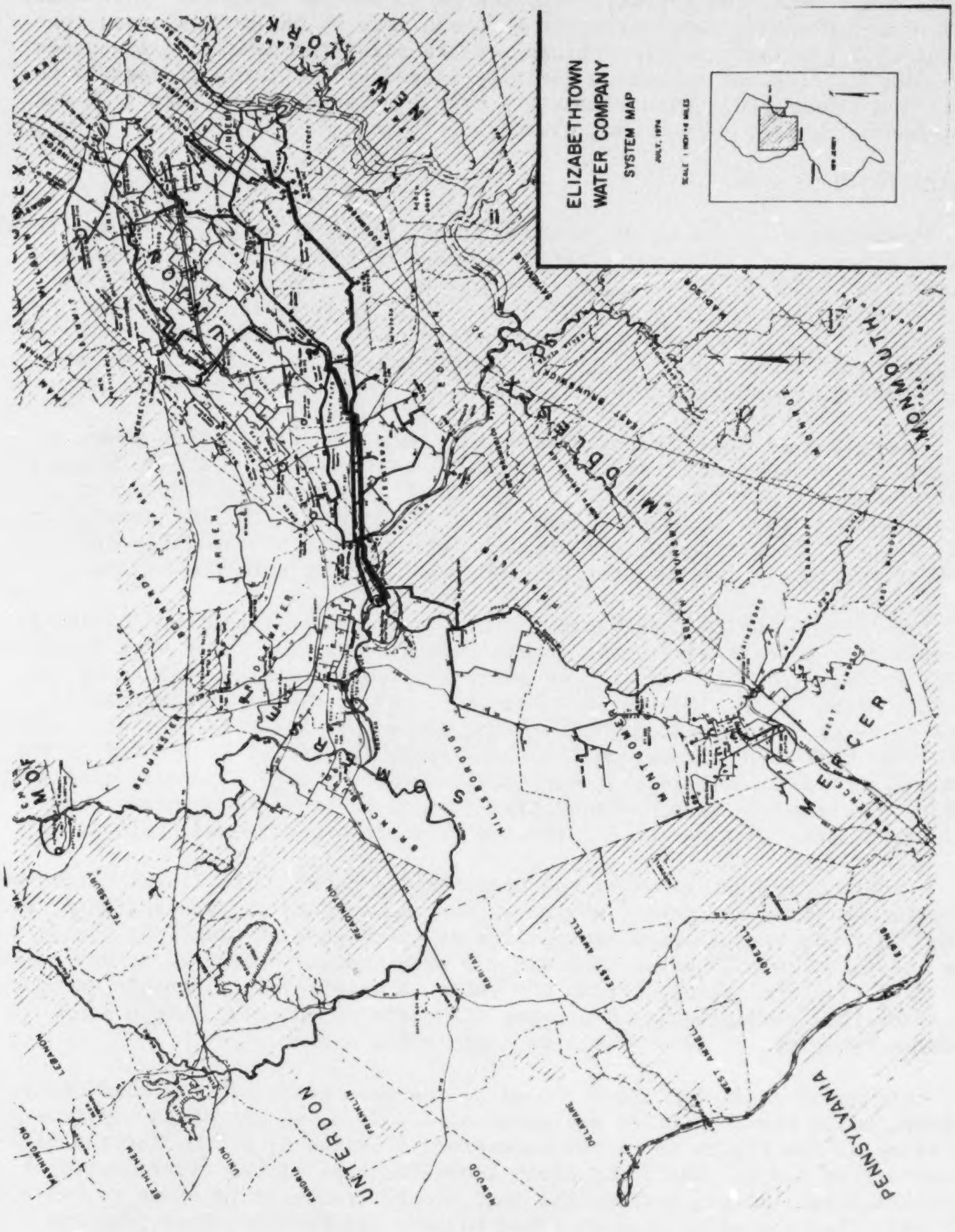

ELIZABETHTOWN WATER COMPANY
SYSTEM MAP
JULY, 1974
NEW YORK
MIDDLESEX
MONMOUTH
MERCER
SOMERSET
HUNTERDON
PENNSYLVANIA
HILLSBOROUGH
MONTGOMERY
BRANCHBURG
BEDMINSTER
READINGTON
EAST AMWELL
WEST AMWELL
DELAWARE
FRANKLIN
TEWKSBURY

Figure 67. Elizabethtown Water Company system map, July, 1974.

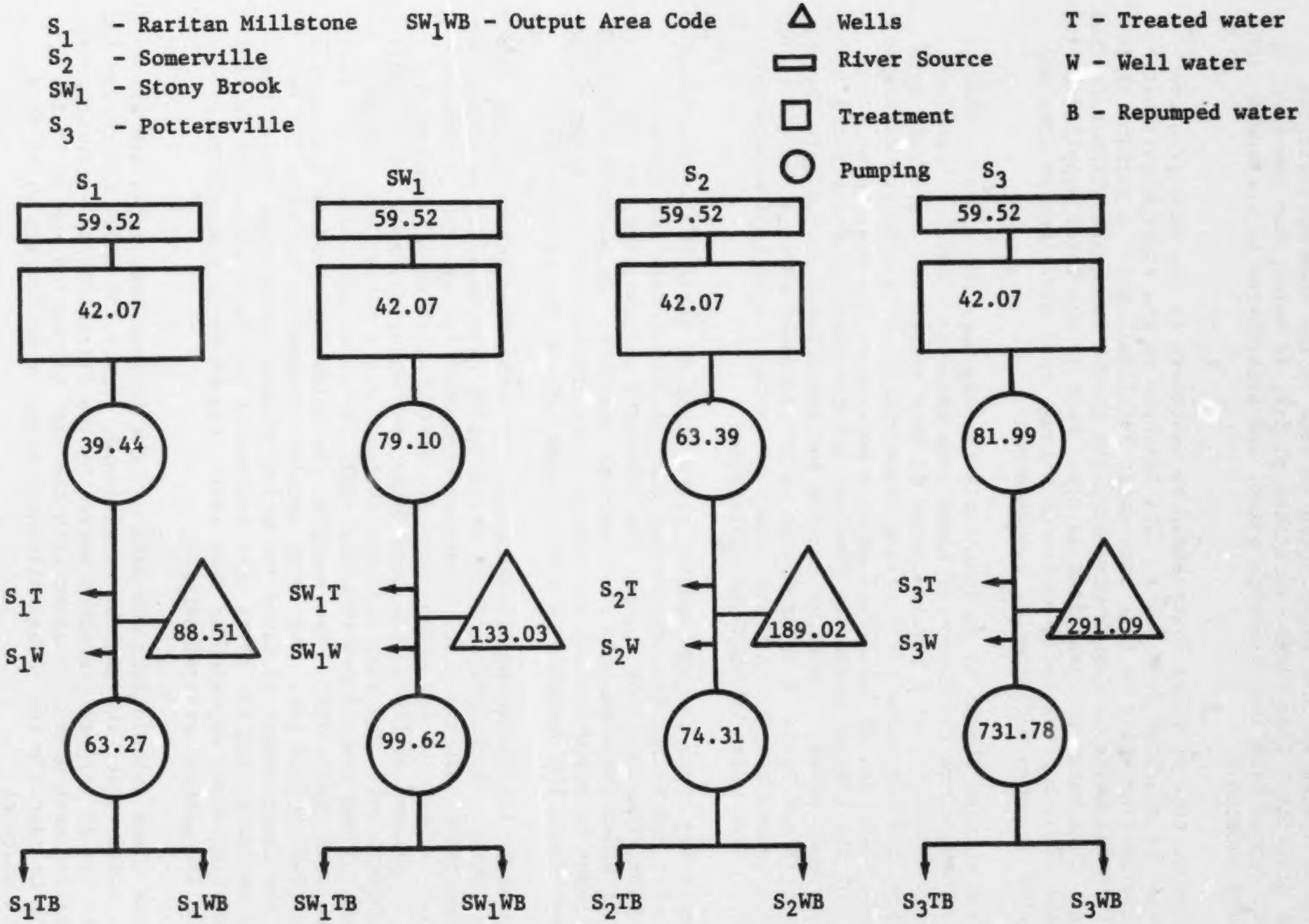

S_1 - Raritan Millstone
S_2 - Somerville
SW_1 - Stony Brook
S_3 - Pottersville
SW_1WB - Output Area Code
Wells
River Source
Treatment
Pumping
T - Treated water
W - Well water
B - Repumped water
S_1
59.52
42.07
39.44
88.51
63.27
S_1T
S_1W
S_1TB
S_1WB
SW_1
59.52
42.07
79.10
133.03
99.62
SW_1T
SW_1W
SW_1TB
SW_1WB
S_2
59.52
42.07
63.39
189.02
74.31
S_2T
S_2W
S_2TB
S_2WB
S_3
59.52
42.07
81.99
291.09
731.78
S_3T
S_3W
S_3TB
S_3WB

Figure 68. Elizabethtown Water Company allocation of capital and operating costs to system components ($/RPW).

from the S_1 system is then distributed to some of the consumers without further activity. This water, indicated as S_1T, is water that has been treated, pumped from the treatment plant, and distributed to customers without being boosted.

Another type of water distributed to customers in the same pressure level will be obtained from wells. The triangle to the right shows that water coming from wells in that area costs $88.51/mil gal. A portion of the water from the wells is distributed directly to the customers without further pumping. This water is identified as S_1W. Part of the water supplied by the treatment plant and the wells passes on through that distribution area and is boosted by pumps into another pressure zone.

As discussed above, it is impossible to determine the specific flow of water and therefore the number of times some water is boosted. Therefore, all costs associated with boosted water in this system are aggregated into one value, and the costs for boosting water within the system are determined. As shown, this cost is $63.27/mil gal. A portion of the well water and a portion of the treated water are boosted, and the water is distributed into other pressure zones. The water boosted and distributed is indicated by the symbols S_1TB and S_1WB. S_1TB indicates water processed through the treatment facility, pumped out, boosted and then distributed. S_1WB indicates water from local area wells boosted and distributed.

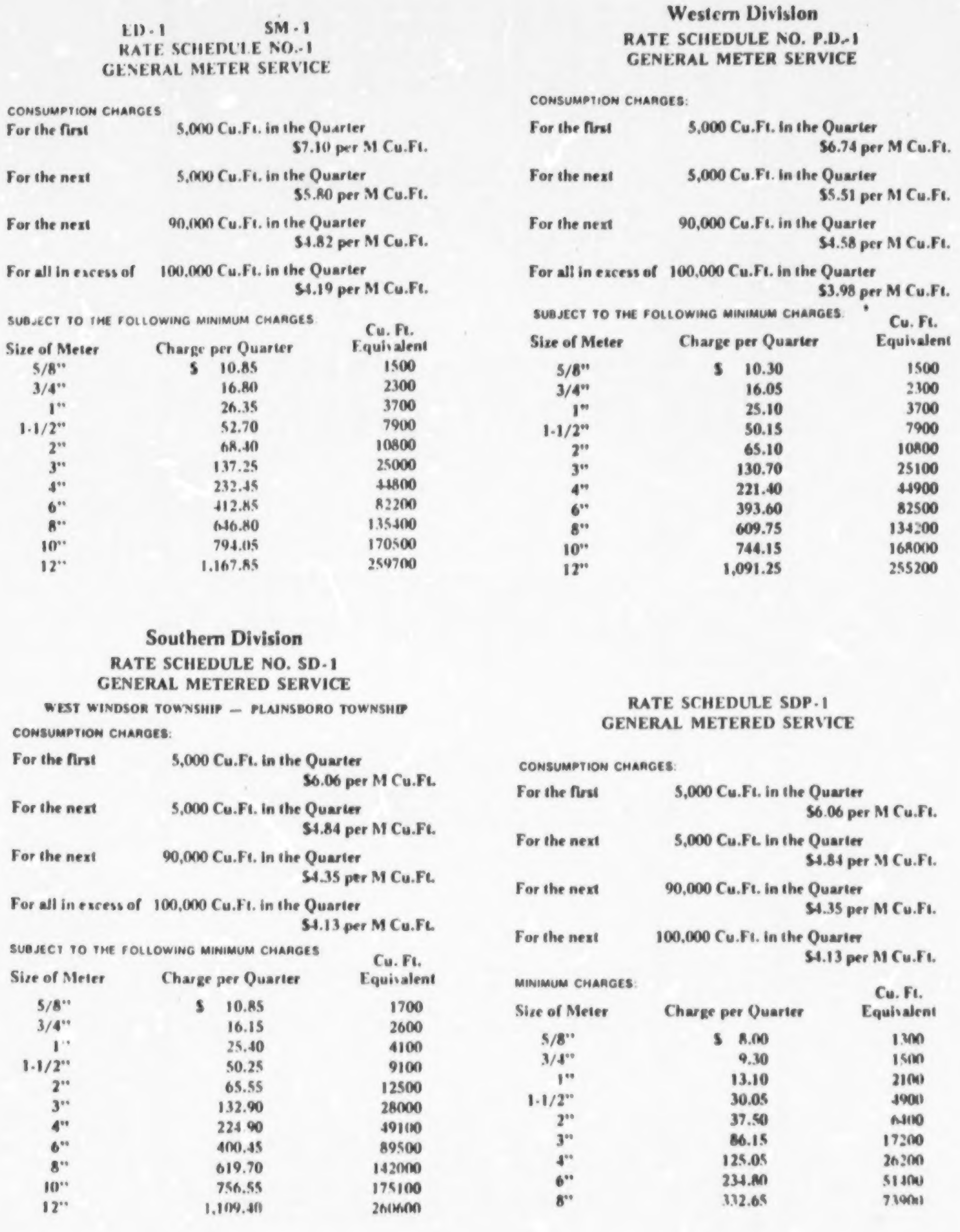
Table 129 shows the incremental costs of water delivered as described above. For S_1T water, the incremental cost of $141.03/mil gal includes acquisition from the river source, the treatment process, and the pumping of the water under pressure from the treatment facility. An additional $63.27/mil gal must be added for the portion of water boosted and then delivered to the area; thus, the incremental cost becomes $204.30 and $151.78/mil gal.

Added to the incremental cost are the distribution, interest, and support services costs. Calculation of the distribution cost is based on the assumption that these unit costs are constant throughout the system. Therefore, the total capital and operating costs for distribution are divided by the number of gallons of RPW in the year under consideration, yielding a figure of $63.33/mil gal. The same approach is taken for interest and support services. These costs added together yield the total unit cost ($/mil gal) for each area (Table 129). For example, the water delivered as S_1T costs a total of $401.02/mil gal. The total metered consumption in Table 129 reflects the total amount of water for which revenue was charged during the year of analysis, and the total cost represents the total amount of capital and operating money expended in that year. Figure 69 is a sample rate schedule for general metered service.

Once these calculations are made and the various cost zones are established, costs versus charges can be examined. Table 130 shows the charge for water to the 10 largest customers served by the Elizabethtown Water Company. By comparing each user's location with the cost allocation table, it is possible to identify the actual allocated costs of delivering water to a specific customer.

TABLE 129. ELIZABETHTOWN SERVICE AREA COST, CONSUMPTION AND REVENUE BY ZONE

Zone	Incremental costs ($/mil gal)	Distribution costs ($/mil gal)	Interest ($/mil gal)	Support services ($/mil gal)	Total cost ($/mil gal)	RPW (mil gal)	Revenue
S_1T	141.03	63.33	113.04	83.62	401.02	19,708.20	7,903,382.36
S_1W	88.51	63.33	113.04	83.62	348.50	5,608.46	1,954,548.31
S_1TB	204.60	63.33	113.04	83.62	464.59	7,768.10	3,608,981.58
S_1WB	151.78	63.33	113.04	83.62	411.77	2,216.60	912,729.38
SW_1T	180.69	63.33	113.04	83.62	440.68	1,231.27	542,596.06
SW_1W	133.03	63.33	113.04	83.62	393.02	391.51	153,871.26
SW_1TB	280.31	63.33	113.04	83.62	540.30	82.31	44,472.09
SW_1WB	232.65	63.33	113.04	83.62	492.64	26.13	12,872.68
S_2T	164.98	63.33	113.04	83.62	424.97	704.25	299,285.12
S_2W	189.02	63.33	113.04	83.62	449.01	6.41	2,878.15
S_2TB	239.29	63.33	113.04	83.62	499.28	477.93	238,620.89
S_2WB	263.33	63.33	113.04	83.62	523.32	4.83	2,527.64
S_3T	183.58	63.33	113.04	83.62	443.57	24.12	10,698.91
S_3W	291.09	63.33	113.04	83.62	551.08	3.97	2,187.79
S_3TB	915.36	63.33	113.04	83.62	1,175.35	1.80	2,115.63
S_3WB	1,022.89	63.33	113.04	83.62	1,282.86	0.29	372.03
Total	---	---	---	---	---	38,256.18	15,692,139.88



ED-1 SM-1
RATE SCHEDULE NO.-1
GENERAL METER SERVICE

CONSUMPTION CHARGES

For the first	5,000 Cu.Ft. in the Quarter	$7.10 per M Cu.Ft.
For the next	5,000 Cu.Ft. in the Quarter	$5.80 per M Cu.Ft.
For the next	90,000 Cu.Ft. in the Quarter	$4.82 per M Cu.Ft.
For all in excess of	100,000 Cu.Ft. in the Quarter	$4.19 per M Cu.Ft.

SUBJECT TO THE FOLLOWING MINIMUM CHARGES

Size of Meter	Charge per Quarter	Cu. Ft. Equivalent
5/8"	$ 10.85	1500
3/4"	16.80	2300
1"	26.35	3700
1-1/2"	52.70	7900
2"	68.40	10800
3"	137.25	25000
4"	232.45	44800
6"	412.85	82200
8"	646.80	135400
10"	794.05	170500
12"	1,167.85	259700

Western Division
RATE SCHEDULE NO. P.D.-1
GENERAL METER SERVICE

CONSUMPTION CHARGES:

For the first	5,000 Cu.Ft. in the Quarter	$6.74 per M Cu.Ft.
For the next	5,000 Cu.Ft. in the Quarter	$5.51 per M Cu.Ft.
For the next	90,000 Cu.Ft. in the Quarter	$4.58 per M Cu.Ft.
For all in excess of	100,000 Cu.Ft. in the Quarter	$3.98 per M Cu.Ft.

SUBJECT TO THE FOLLOWING MINIMUM CHARGES:

Size of Meter	Charge per Quarter	Cu. Ft. Equivalent
5/8"	$ 10.30	1500
3/4"	16.05	2300
1"	25.10	3700
1-1/2"	50.15	7900
2"	65.10	10800
3"	130.70	25100
4"	221.40	44900
6"	393.60	82500
8"	609.75	134200
10"	744.15	168000
12"	1,091.25	255200

Southern Division
RATE SCHEDULE NO. SD-1
GENERAL METERED SERVICE

WEST WINDSOR TOWNSHIP — PLAINSBORO TOWNSHIP

CONSUMPTION CHARGES:

For the first	5,000 Cu.Ft. in the Quarter	$6.06 per M Cu.Ft.
For the next	5,000 Cu.Ft. in the Quarter	$4.84 per M Cu.Ft.
For the next	90,000 Cu.Ft. in the Quarter	$4.35 per M Cu.Ft.
For all in excess of	100,000 Cu.Ft. in the Quarter	$4.13 per M Cu.Ft.

SUBJECT TO THE FOLLOWING MINIMUM CHARGES

Size of Meter	Charge per Quarter	Cu. Ft. Equivalent
5/8"	$ 10.85	1700
3/4"	16.15	2600
1"	25.40	4100
1-1/2"	50.25	9100
2"	65.55	12500
3"	132.90	28000
4"	224.90	49100
6"	400.45	89500
8"	619.70	142000
10"	756.55	175100
12"	1,109.40	260600

RATE SCHEDULE SDP-1
GENERAL METERED SERVICE

CONSUMPTION CHARGES:

For the first	5,000 Cu.Ft. in the Quarter	$6.06 per M Cu.Ft.
For the next	5,000 Cu.Ft. in the Quarter	$4.84 per M Cu.Ft.
For the next	90,000 Cu.Ft. in the Quarter	$4.35 per M Cu.Ft.
For the next	100,000 Cu.Ft. in the Quarter	$4.13 per M Cu.Ft.

MINIMUM CHARGES:

Size of Meter	Charge per Quarter	Cu. Ft. Equivalent
5/8"	$ 8.00	1300
3/4"	9.30	1500
1"	13.10	2100
1-1/2"	30.05	4900
2"	37.50	6400
3"	86.15	17200
4"	125.05	26200
6"	234.80	51400
8"	332.65	73900

Figure 69. Elizabethtown Water Company meter rates.

TABLE 130. ELIZABETHTOWN WATER COMPANY WATER COSTS FOR 10 MAJOR USERS

Major user	High or low month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Cost zone
Newark, City	High	403.6	$73,053	$181.00	S_1TB
	Low	160.1	28,972	180.96	
Commonwealth Water Co.	High	275.9	58,215	211.00	S_1TB
	Low	243.3	51,331	210.98	
Elizabeth, City	High	226.7	47,842	211.04	S_1TB
	Low	163.3	34,451	210.97	
Edison, Township	High	168.0	35,376	210.57	S_1T
	Low	124.2	28,534	229.74	
Middlesex Water Co.	High	125.0	26,408	211.26	S_1T
	Low	113.5	24,079	212.15	
Public Service	High	124.2	36,960	297.58	S_1TB
	Low	71.3	26,165	366.97	
Franklin, Township	High	103.2	21,765	210.90	S_1T
	Low	67.1	14,151	210.89	
Bound Brook Water Co.	High	70.5	14,875	210.99	S_1T
	Low	51.2	10,799	210.92	
Exxon	High	78.5	24,246	308.87	S_1TB
	Low	38.8	13,210	340.46	
Highland Park, Borough	High	62.7	13,232	211.04	S_1T
	Low	48.1	10,342	215.01	

The Elizabethtown water service area is shown in Figure 70 with the top 10 customers identified. Though it is not possible to identify the specific zones, it is easy to see that most of the top customers (the cities of Newark and Elizabeth and several of the water companies) lie outside the normal distribution area, and for that reason are assumed to receive boosted water. It should be noted (Table 129) that the lowest total cost for boosted water is for S_1WB, which totals $411.77 (actual cost/mil gal) to deliver to that point.

The average unit costs for all water supplied during the most recent year studied are as follows:

	$/mil gal
Support services--------	89
Acquisition-------------	67
Treatment---------------	33
Distribution------------	144
Interest----------------	113
Taxes-------------------	76
Total-------------------	492

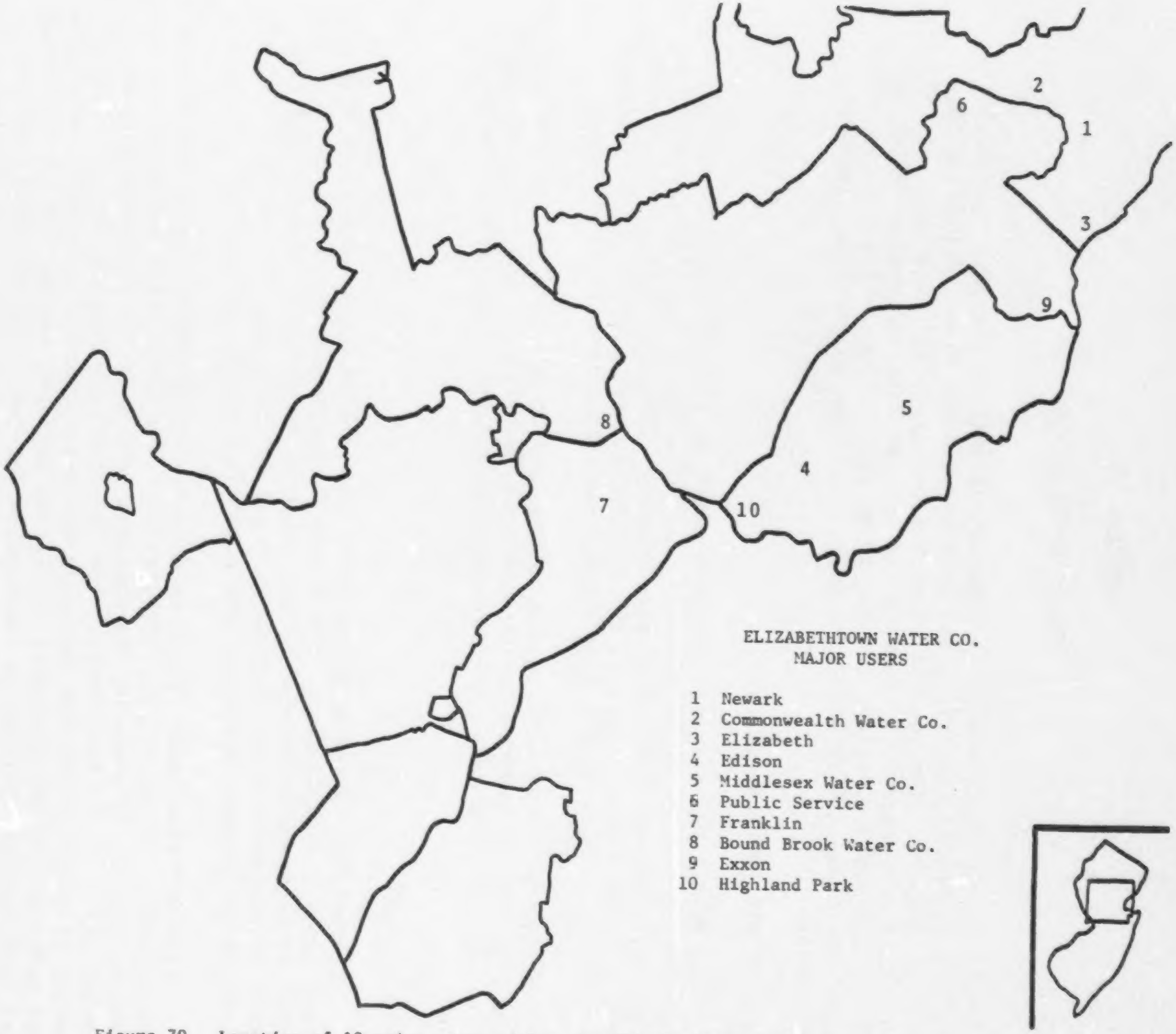

ELIZABETHTOWN WATER CO.
MAJOR USERS
1 Newark
2 Commonwealth Water Co.
3 Elizabeth
4 Edison
5 Middlesex Water Co.
6 Public Service
7 Franklin
8 Bound Brook Water Co.
9 Exxon
10 Highland Park
1
2
3
4
5
6
7
8
9
10

Figure 70. Location of 10 major users within the Elizabethtown Water Company service area.

SECTION 15

PUEBLO WATER SYSTEM

The Pueblo Water System is a municipal utility providing water to the citizens of Pueblo, Colorado, and to some adjacent areas, including the Memorial Airport. The population of the county in 1974 was just over 127,000. The retail service area, primarily the City of Pueblo, provides water to 108,000 customers. During the past 10 years, the population and the water demand have remained relatively stable. Some system facts are given in Table 131.

WATER SUPPLY SERVICE AREA

The Pueblo Water System provides water on a retail basis to all classes of customers within the service area shown in Figure 71. Treated water is primarily supplied to citizens and industry within the city limits and to some outlying areas, including the Pueblo Memorial Airport on the east side of the city. This service area encompasses approximately 56 sq miles.

Growth is anticipated in the future, and it is expected that the service area will expand somewhat to the east, but primarily to the north and southwest. By the year 2,000, the service area will more than double its present size.

ORGANIZATION

Because the system supplies water only, it is not intermingled with any other service organization. The system is controlled by five members of the Board of Waterworks, elected by the citizens to serve a 6 year term. This Board is responsible for long-range plans insuring that the water system is operated in the most efficient and economical manner possible.

Five division heads report to an executive director who is responsible for operation of the utility (Figure 72). The Engineering Division is responsible for determining the equipment and facility requirements and construction of the facilities. The Treatment and Pumping Division is primarily responsible for the operation and maintenance of treatment facilities and pumping from the treatment facilities into the system. The Transmission and Distribution Division is responsible for operation and maintenance related to moving the water from the treatment facilities to the customers and for storage within the distribution system. The Finance Division is responsible for maintaining financial records and billing and collecting. The

TABLE 131. PUEBLO WATER UTILITY, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	N/A
County	127,092
Retail service area (city)	108,028
Area of retail service area (estimated sq miles)	56
Recognized customer classes (number of accounts)	
City resident	27,292
County resident	247
City commercial	1,664
County commercial	21
Flat rate	2
Church and charity	136
Percent metered	100
Purchased water	None
Source water	100% Surface
Pipe in system (estimated miles)	300
Elevation of treatment plants	
North Ft.	4,695
South Ft.	4,695
Elevation of service area (min/max ft)	4600/5050 (1402/1539)
Revenue-producing water (mil gal)	6,845
Treated water (mil gal)	9,854
Maximum day/maximum hour (MGD)	51/82

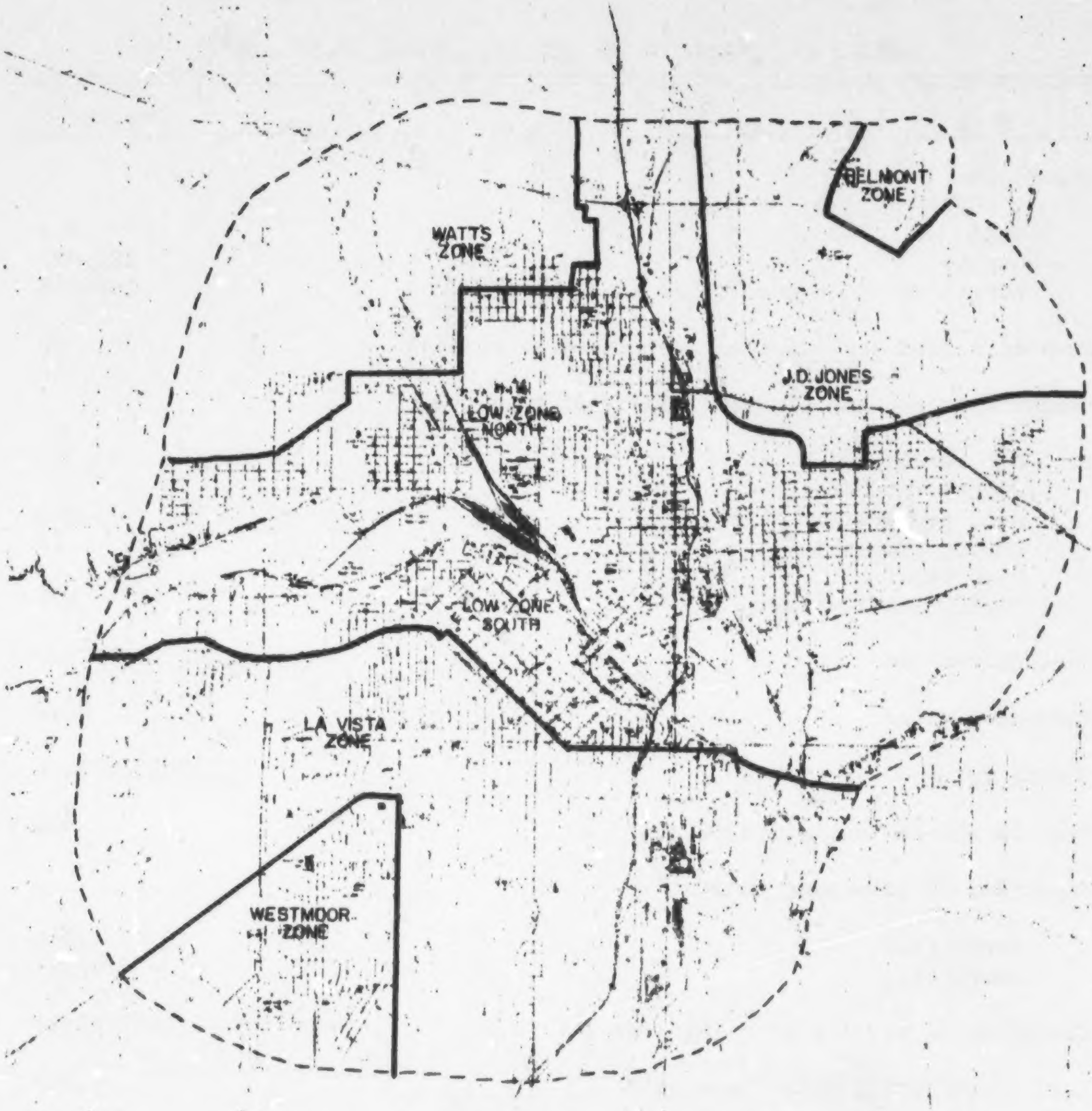

WATTS ZONE
BELMONT ZONE
J.D. JONES ZONE
LOW ZONE NORTH
LOW ZONE SOUTH
LA VISTA ZONE
WESTMOOR ZONE

Figure 71. Pueblo Water System retail service area.

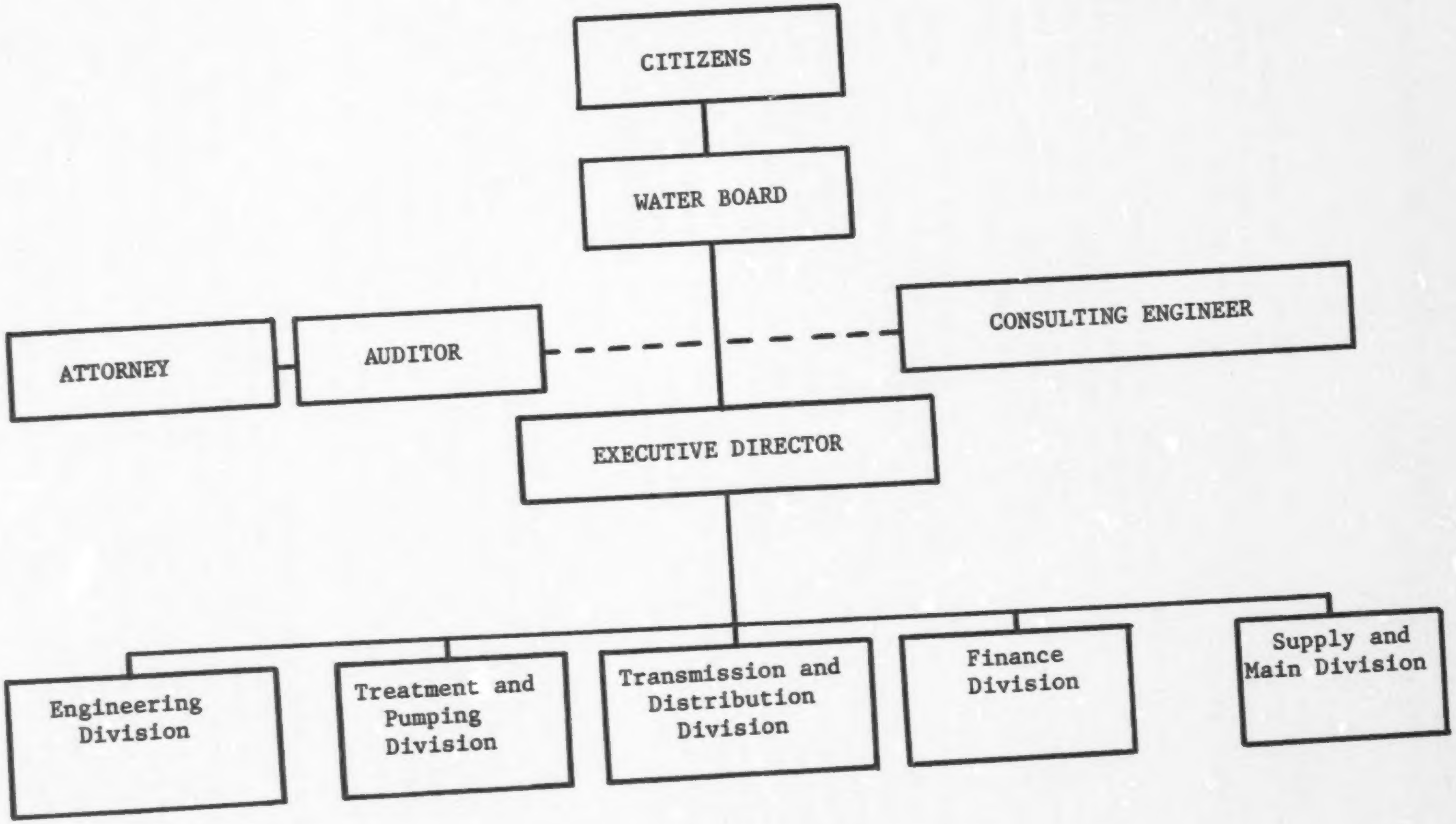

CITIZENS
WATER BOARD
ATTORNEY
AUDITOR
CONSULTING ENGINEER
EXECUTIVE DIRECTOR
Engineering Division
Treatment and Pumping Division
Transmission and Distribution Division
Finance Division
Supply and Main Division

Figure 72. Pueblo Water Utility organizational chart.

Supply and Mains Division is primarily responsible for maintaining the system that supplies raw water to the utility.

ACQUISITION

Raw water is taken from the Arkansas River. Because Pueblo is located in an area with a semi-arid climate and at times is subject to water shortage, the system acted to obtain water rights in excess of that normally provided by the Arkansas River.

Pueblo's water supply is composed of three types of rights: (1) nonstorable direct flow water from the Arkansas River, (2) storable water diverted from the western slope of the Rocky Mountains into the Arkansas River Basin, and (3) rights to store eastern slope water in Clear Creek reservoir. These watershed areas and storage points are located 140 river miles or more to the west of Pueblo in the Rocky Mountains near Leadville, Colorado.

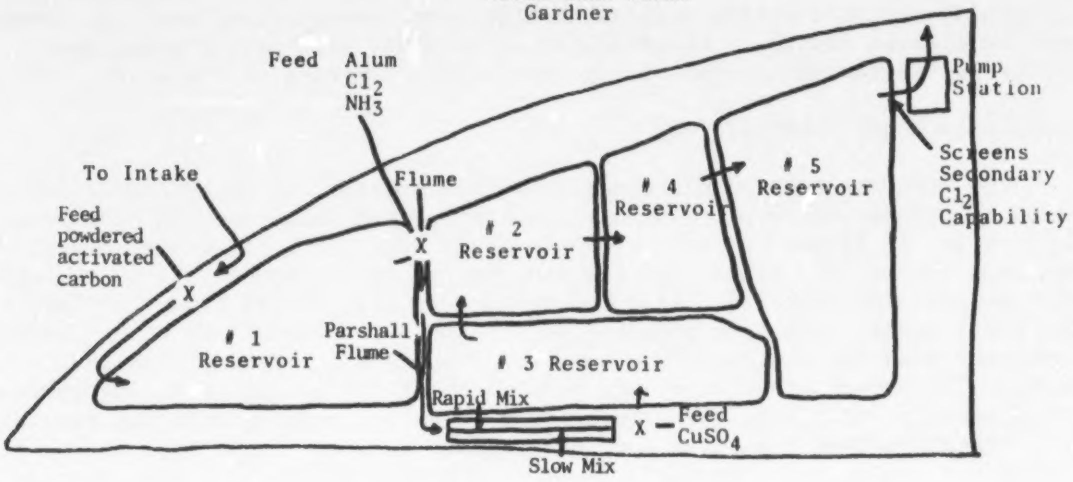
Pueblo's water rights consist of 34 mil gal of nonstorable water a day from the Arkansas River. To supplement direct flow rights, the Water Board purchased transmountain diversion facilities to transport water from the western slopes of the Rocky Mountains. In 1955, the Board purchased Clear Creek reservoir, which provides 11,232 acre ft of storage space for Pueblo's storable transmountain water. In recent years, the Pueblo Water Board acquired excessive direct flow and transmountain rights for Pueblo's future development. The largest of these is Pueblo's portion of the Twin Lakes diversion system, which alone could support enough water for 50,000 people. From 1967 to 1973, $23 million was spent for water rights to insure Pueblo's orderly growth and development. The present water supply is capable of supporting 230,000 people plus the water needs of the Comanche Power Station.

TREATMENT

Pueblo has two water treatment plants. The Gardner Plant, located on the north side of the Arkansas River, produces 25 MGD, and the McCabe plant, located on the south side of the river directly across from the Gardner plant, produces 15 MGD, providing a total capacity of 40 MGD of treated water. The present treatment process of both plants (Figure 73) removes turbidity and bacteria by sedimentation and flocculation, which depend on gravity aided by chemicals. Each plant uses dry feed machines, mixers, and chlorinators to feed the chemicals in the prescribed amounts into the system.

Water enters each plant through an inlet flume from the Arkansas River to the initial settling basin. Activated carbon is added to the water in the flume and basin to remove any objectionable taste or odor. Heavier particles settle to the bottom, and the water moves slowly to the flash mixers at the beginning of the flocculation tanks. Aluminum sulfate is added and violently flash-mixed by electrically driven blades. This chemical forms jelly-like particles (floc) that attract foreign matter. Slow mixers throughout the tank encourage the formation of floc. As a floc attracts foreign particles, it becomes heavy and sinks to the bottom of the basin. Copper sulfate is added at the end of the flocculation tanks to retard the growth of algae.

North Side Plant
Gardner


Feed
Alum
Cl_2
NH_3
To Intake
Flume
Feed powdered activated carbon
X
X
# 1 Reservoir
# 2 Reservoir
# 3 Reservoir
# 4 Reservoir
# 5 Reservoir
Parshall Flume
Rapid Mix
Slow Mix
X
Feed $CuSO_4$
Pump Station
Screens Secondary Cl_2 Capability

South Side Plant

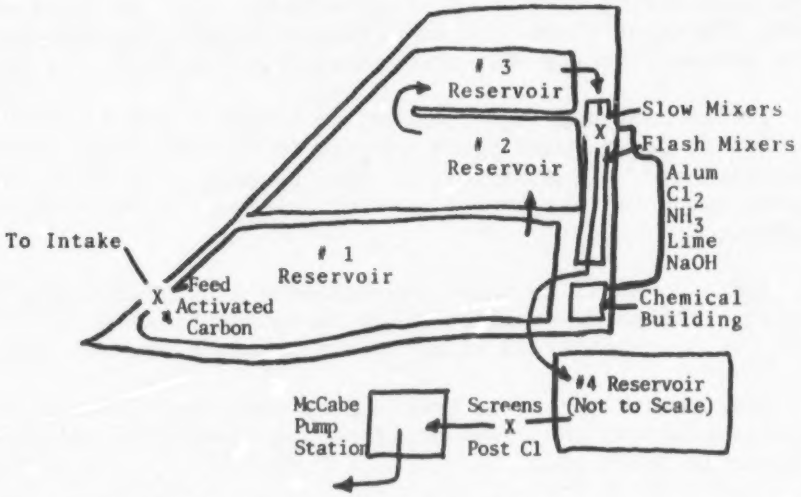

# 3 Reservoir
# 2 Reservoir
# 1 Reservoir
Slow Mixers
X
Flash Mixers
Alum
Cl_2
NH_3
Lime
NaOH
Chemical Building
To Intake
X
Feed Activated Carbon
#4 Reservoir (Not to Scale)
Screens
X
Post Cl
McCabe Pump Station

Figure 73. Pueblo Water Utility water treatment facilities.

Chlorine is added to the water to kill any objectionable bacteria, and at the same time, ammonium sulfate is added to combine with the chlorine and form chloramine. These compounds reduce the chlorine taste and enable chlorine to stay in the solution longer.

Filtration, the final step in water treatment, was put into operation during the summer of 1976 at the Northside Treatment Plant. Filtration is especially critical during periods of high water consumption, when the water must be treated rapidly. Chemically treated water will pass through sand filters to guarantee removal of any impurities remaining in the water.

TRANSMISSION AND DISTRIBUTION

The transmission and distribution system consists of an estimated 300 miles of underground pipe. The distribution system mains vary in size from 2 to 48 in. in diameter. Most of the pipe is cast iron, but wooden stave, asbestos cement, and steel pipe are also in service. Much of the cast iron pipe is unlined, which has permitted rapid corrosion of the pipe interior. In recent years, cast iron pipes lined with asbestos cement and cement mortar have been used for the smaller mains, and lined steel pipes for the larger mains. The wooden stave pipes are some of the first installed in the system and presently are giving adequate service, although tapping into and repairing the wood pipes have presented some maintenance problems.

Located in Pueblo along the edge of the city are eight clear water reservoir areas with a total storage capacity of over 42 mil gal; these help to balance the water supply and demand. Treated water is pumped into these reservoirs during periods of slack consumption. When the demand for water is heavy, the water flows from the reservoirs into the mains supplementing supplies pumped directly into the system from the treatment plants.

In the nine pumping stations, 28 electric motors from 50 to 700 hp are attached to centrifugal pumps varying in capacity from 1,750 to 10,000 gallons/minute. In addition, at most pumping locations there are large diesel engines ready to take over the water delivery in the event of a general power failure.

A 42-in. pipeline under the Arkansas River links the Gardner and McCabe pumping stations together to allow emergency flexibility. During peak loads, water can be transferred either north or south, as the need arises.

Additional storage is provided by concrete subsurface and ground tanks, steel standpipes, and elevated tanks. A description of the storage capability is given in Table 132.

COST ANALYSIS

The demand for water from 1965 through 1974 is shown in Figure 74.

Using the standard cost categories, data were collected and reported as shown in Tables 133, 134, and 135.

TABLE 132. PUEBLO WATER UTILITY STORAGE FACILITIES

Name of facility	Overflow elevation (ft)	Capacity (mil gal)
Watts Reservoir	4903	6
J. O. Jones (4 Tanks)	4919	12
Belmont (2 Tanks)	5008	6
Belmont	5065	1
Watts Elevated	5029	1
Aberdeen	4915	1
Lavista	4987	8
Hellbeck Elevated	4975	2
Westmoor	5150	6
Airport	4650	1

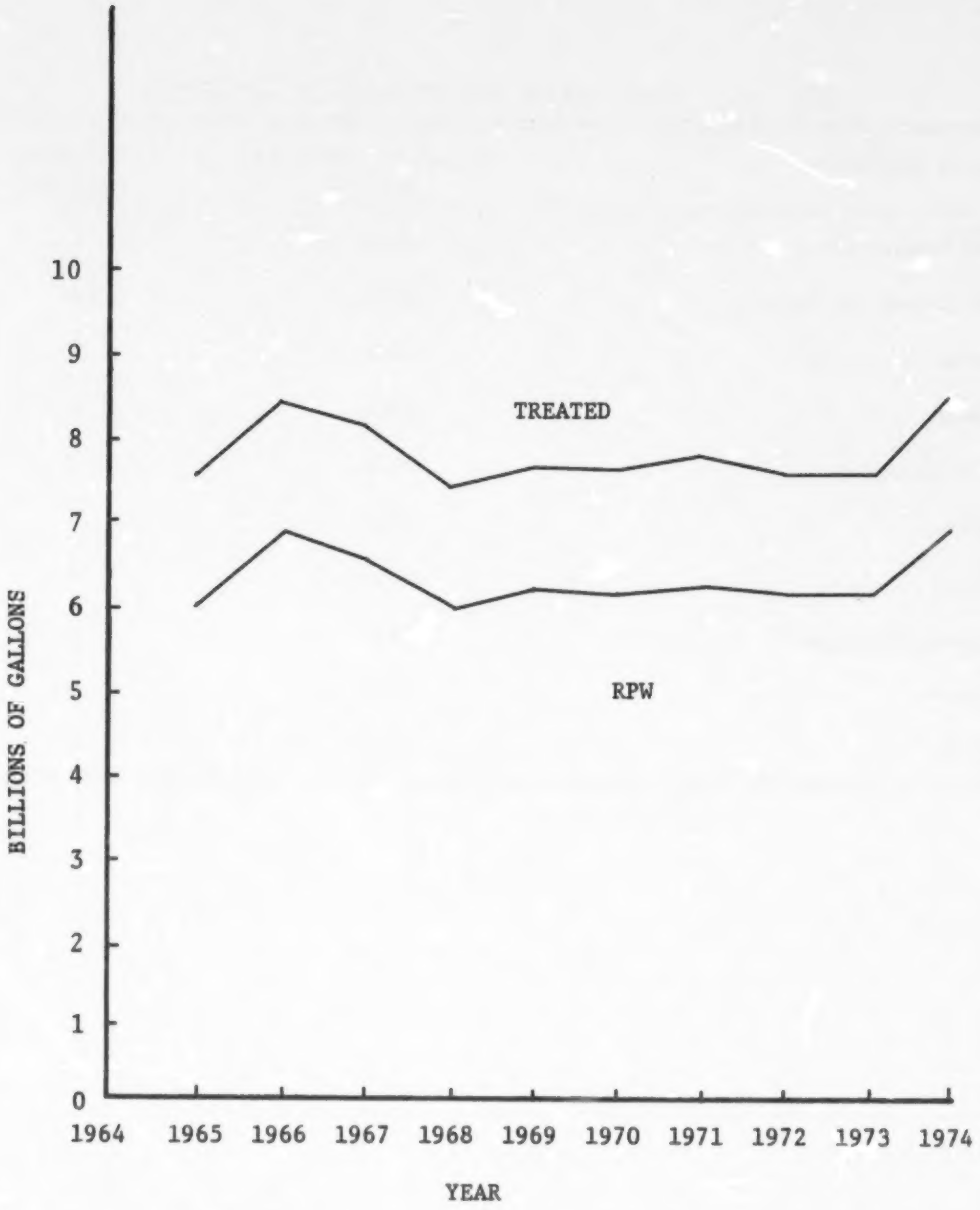


Figure 74. Pueblo Water Utility water flow:
treated water versus RPW.

TABLE 133. PUEBLO WATER UTILITY ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$146,483	$170,247	$141,821	$170,169	$149,303	$176,539	$155,408	$166,159	$204,314	$189,632
Accounting and collection	163,585	149,739	186,606	175,545	188,538	214,604	248,000	274,611	288,007	322,647
Engineering	---	---	---	38,293	45,118	55,187	58,485	73,767	93,316	92,677
Other	46,119	44,539	45,580	49,194	50,753	43,584	89,554	113,986	85,861	118,124
Total support services	356,187	364,525	374,207	433,201	433,712	490,914	551,447	628,523	671,498	723,080
Acquisition:										
Supervision and labor	15,019	6,471	5,595	22,524	15,663	23,855	18,686	24,403	29,871	42,935
Water development	---	---	---	---	---	---	---	22,367	32,097	36,586
Other	12,881	11,403	5,953	11,894	16,894	11,714	29,135	14,087	25,455	123,326
Total acquisition	27,900	17,874	11,548	34,418	32,557	35,569	47,821	60,857	87,423	202,847
Treatment:										
Supervision and labor	118,852	124,827	119,123	125,429	130,797	146,756	158,494	164,001	188,695	203,810
Chemicals	125,759	142,178	150,652	135,000	136,337	161,413	165,200	168,459	166,166	216,515
Other	38,124	44,972	61,264	70,301	80,920	76,081	92,711	77,532	113,314	107,880
Total treatment	282,735	311,977	331,039	330,730	348,054	384,250	416,405	409,992	468,175	528,205
Power and pumping:										
Supervision and labor	117,268	118,902	128,394	131,292	128,192	116,916	115,947	120,237	120,605	113,657
Power and fuel	163,731	142,672	142,054	144,732	151,443	151,673	150,485	159,748	167,750	205,127
Other	26,877	25,434	39,425	42,154	44,728	35,626	45,221	39,660	45,722	43,303
Total power and pumping	280,876	287,008	309,873	318,178	324,363	304,215	311,653	319,645	334,007	362,087
Transmission and distribution:										
Supervision and labor	183,402	211,780	199,061	156,207	178,359	186,656	200,128	248,516	280,891	322,787
Maintenance	44,025	36,988	18,155	49,754	55,765	54,618	68,035	69,071	89,812	152,204
Other	25,157	24,974	48,527	58,568	77,750	82,687	81,370	94,258	136,938	161,287
Total transmission and distr.	252,584	273,742	265,743	264,529	311,879	323,961	349,533	411,845	507,641	646,278
Total operating cost	1,200,282	1,255,126	1,289,201	1,381,056	1,450,565	1,538,909	1,676,859	1,830,862	2,068,814	2,462,497
Equipment rental credit*	---	---	---	---	52,462	41,002	47,866	49,250	79,840	83,448

* Must be deducted to produce operating and maintenance costs used in Tables 138 and 139.

TABLE 134. PUEBLO WATER UTILITY UNIT OPERATING COSTS/($/mil gal RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$24.50	$25.47	$21.88	$28.51	$24.47	$29.00	$25.33	$27.60	$34.02	$27.92
Accounting and collection	27.36	22.41	28.82	29.41	30.90	35.41	40.42	45.62	47.95	47.50
Engineering	---	---	---	6.42	7.39	9.06	9.53	12.35	15.54	13.64
Other	7.71	6.66	7.03	8.24	8.32	7.16	14.59	18.93	14.30	17.39
Total support services	59.57	54.55	57.75	72.59	71.08	80.64	89.87	104.41	111.80	106.44
Acquisition:										
Supervision and labor	2.51	0.97	0.86	3.77	2.57	3.92	3.05	4.05	4.97	6.32
Water development	---	---	---	---	---	---	---	3.72	5.34	5.39
Other	2.15	1.71	0.92	1.99	2.78	1.92	4.75	2.34	4.24	18.15
Total acquisition	4.67	2.67	1.78	5.77	5.34	5.84	7.79	10.11	14.56	29.86
Treatment:										
Supervision and labor	19.88	18.68	18.38	21.02	21.44	24.11	25.83	27.24	31.42	30.00
Chemicals	21.03	21.27	23.24	22.62	22.34	26.51	26.92	27.98	27.67	31.87
Other	6.36	6.73	9.45	11.78	13.26	12.50	15.11	12.88	18.87	15.88
Total treatment	47.29	46.68	51.07	55.42	57.04	63.12	67.86	68.10	77.95	77.76
Power and pumping:										
Supervision and labor	19.51	17.79	19.81	22.00	21.01	19.20	18.90	19.97	20.08	16.73
Power and fuel	27.38	21.35	21.92	24.25	24.82	24.91	24.52	26.54	27.93	30.20
Other	4.50	3.81	6.08	7.06	7.33	5.85	7.37	6.59	7.61	6.37
Total pumping	46.98	42.95	47.81	53.31	53.16	49.97	50.79	53.10	55.62	53.30
Transmission and distribution:										
Supervision and labor	30.67	31.69	30.71	26.17	29.23	30.66	32.62	41.28	46.77	48.99
Maintenance	7.36	5.53	2.80	8.34	9.14	8.97	11.09	11.47	14.95	22.41
Other	4.21	3.74	7.49	9.81	12.74	13.58	13.26	15.66	22.80	23.74
Total transmission and distribution	42.45	40.96	41.00	44.32	51.11	53.21	56.96	86.41	84.52	95.14
Total unit operating cost	200.75	187.81	198.89	231.41	237.72	252.78	273.28	304.13	344.46	362.51
Equipment rental credit*	---	---	---	---	8.60	6.73	7.80	8.18	13.29	12.28

---

* Must be deducted to produce operating and maintenance costs used in Tables 138 and 139.

TABLE 135. PUEBLO WATER UTILITY OPERATING COSTS AS PERCENT OF TOTAL

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
		1966								
Support services:										
Administration	12.20	13.56	11.00	12.32	10.29	11.47	9.27	9.08	9.88	7.70
Accounting and collection	13.63	11.93	14.49	12.71	13.00	14.01	14.79	15.00	13.92	13.10
Engineering	---	---	---	2.77	3.11	3.58	3.49	4.03	4.51	3.76
Other	3.84	3.55	3.53	3.56	3.50	2.83	5.34	6.22	4.15	4.80
Total support services	29.67	29.05	29.04	31.37	29.90	31.90	32.89	34.33	32.46	29.36
Acquisition:										
Supervision and labor	1.25	0.52	0.43	1.63	1.08	1.55	1.12	1.33	1.44	1.74
Water development	---	---	---	---	---	---	---	1.22	1.55	1.49
Other	1.07	0.91	0.46	0.36	1.17	0.76	1.74	0.77	1.23	5.01
Total acquisition	2.33	1.42	0.89	2.49	2.25	2.31	2.85	3.32	4.23	8.24
Treatment:										
Supervision and labor	9.90	9.95	9.24	9.08	9.02	9.54	9.45	8.96	9.12	8.28
Chemicals	10.48	11.33	11.68	9.77	9.40	10.49	9.85	9.20	8.03	8.79
Other	3.17	3.58	4.75	5.09	5.58	4.95	5.53	4.24	5.48	4.38
Total treatment	23.56	24.85	24.68	23.95	23.99	24.97	24.83	22.39	22.63	21.45
Power and pumping:										
Supervision and labor	9.72	9.47	9.96	9.51	8.84	7.60	6.92	6.57	5.83	4.62
Power and fuel	13.64	11.37	11.02	10.48	10.44	9.85	8.97	8.73	8.11	8.33
Other	2.24	2.03	3.06	3.05	3.08	2.31	2.70	2.17	2.21	1.76
Total pumping	23.40	22.87	24.04	23.04	22.36	19.77	18.59	17.46	16.15	14.70
Transmission and distribution:										
Supervision and labor	15.28	16.87	15.44	11.31	12.30	12.13	11.94	13.57	13.58	13.51
Maintenance	3.67	2.94	1.41	3.60	3.84	3.55	4.06	3.77	4.34	6.18
Other	2.10	1.99	3.77	4.24	5.36	5.37	4.85	5.15	6.62	6.55
Total transmission and distribution	21.05	21.81	20.61	19.15	21.50	21.05	20.84	28.41	24.54	26.24

Table 136 examines labor costs. The cost/man-hour increased 54% over the 10-year period, whereas the total payroll hours required to produce 1 mil gal of RPW remained approximately constant. During that time, there was some fluctuation above and below the manpower requirement in 1965, with most of the fluctuation less than the 1965 requirements. However, in 1974, requirements returned to almost the same value. Thus at least a large portion of the operating cost increased at the same rate as labor cost in a per-man-hour basis.

Table 137 summarizes the operating, depreciation, and interest expenses for the 10-year period of analysis. Table 138 computes capital and operating expense ratios. The operating expenses are those shown as a total of the values in Table 133, the expenses incurred in the normal day-to-day operations of the system. The capital expenses are the total periodic expenditures for major equipment items and facilities plus interest charged on money borrowed for those purposes.

A comparison of the operating and capital expenses as a percent of total shows that in the Pueblo Water System, more expenses are associated with operations than with capital. Over the 10-year period, the trend changed in the direction of capital. In 1965, 65% of the total expended was for operating expense, and 35% was for capital. This ratio changed gradually over the 10 years, with an increased portion of the expenses going toward capital. By 1974, the ratio was 57% for operations and 43% for capital.

The Pueblo Water System's basic equipment, including much of the distribution system and the treatment facilities, is relatively old. During the last 10 years, however, a sizable capital expenditure has been made for water rights and also some for facility improvements. Most of the capital expenditures have been associated with water rights that have little effect on the present operating system but would cause a significant impact on the depreciated capital. These water rights certainly do put the system in a solid position for future operations. A condition such as this, with increasing capital costs compounded with increasing operational costs, causes rapid escalation in total cost for the production of water. This trend can be seen by examining the total cost/mil gal of RPW (Table 137). Examination of the figures for the total 10-year period points up this trend, especially from 1972 through 1974, when the cost of producing water increased rapidly.

SYSTEM COSTS

Examination of the costs on a functional basis is only part of the toatl picture. Because the purpose of the water utility is to deliver water to a customer, it is important to present costs as they relate water delivery to the demand point within the distribution system. The functional categories, both operating and capital, are therefore reaggregated and assigned to physical components in the water delivery system. This section contains such an analysis of the water supply system cost.

Locations of the Pueblo Water System's facilities are shown in Figure 75. Unfortunately, data were not available in the utility's records that would

TABLE 136. PUEBLO WATER UTILITY LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	653,721	684,597	666,851	670,876	701,103	759,714	821,138	911,971	1,037,755	1,139,840
Total hours on payroll	257,920	257,920	257,920	255,840	260,000	237,120	245,440	260,000	282,880	293,280
Revenue-producing water (mil gal)	5,979	6,683	6,482	5,968	6,102	6,088	6,136	6,020	6,006	6,793
Total payroll/mil gal RPW ($)	109.34	102.44	102.88	112.41	114.90	124.79	133.82	151.49	172.79	167.80
Total hours/mil gal RPW	43.14	38.59	39.79	42.87	42.61	38.95	40.00	43.19	47.10	43.17
Average cost/man-hour ($)	2.53	2.65	2.59	2.62	2.70	3.20	3.35	3.51	3.67	3.89

TABLE 137. PUEBLO WATER UTILITY CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	1,200,282	1,255,126	1,289,201	1,381,056	1,398,103	1,497,907	1,628,993	1,781,612	1,988,974	2,379,049
Depreciation ($)	356,407	382,861	463,505	507,538	557,091	568,425	585,038	620,704	657,430	692,620
Interest	277,956	264,575	249,671	235,081	228,919	248,540	270,053	318,430	801,726	1,115,858
Total cost	1,834,645	1,902,562	2,002,377	2,123,675	2,184,113	2,314,872	2,484,084	2,270,746	3,448,130	4,187,527
Total unit cost/($/mil gal RPW)	306.85	284.69	308.91	355.84	357.93	380.24	404.84	451.95	574.11	616.45

TABLE 138. PUEBLO WATER UTILITY CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	1,200,282	1,255,126	1,289,201	1,381,056	1,398,103	1,497,907	1,628,993	1,781,612	1,988,974	2,379,049
Capital expense ($)	634,363	647,436	713,176	742,619	786,010	816,965	855,091	939,134	1,459,156	1,808,478
Total ($)	1,834,645	1,902,562	2,002,377	2,123,675	2,184,113	2,314,872	2,484,084	2,720,746	3,448,130	4,187,527
Operating expense as % of total	65.42	65.97	64.38	65.03	64.01	64.71	65.57	65.48	57.68	56.81
Capital expense as % of total	34.58	34.03	35.62	34.97	35.99	35.29	34.43	34.52	42.32	43.19

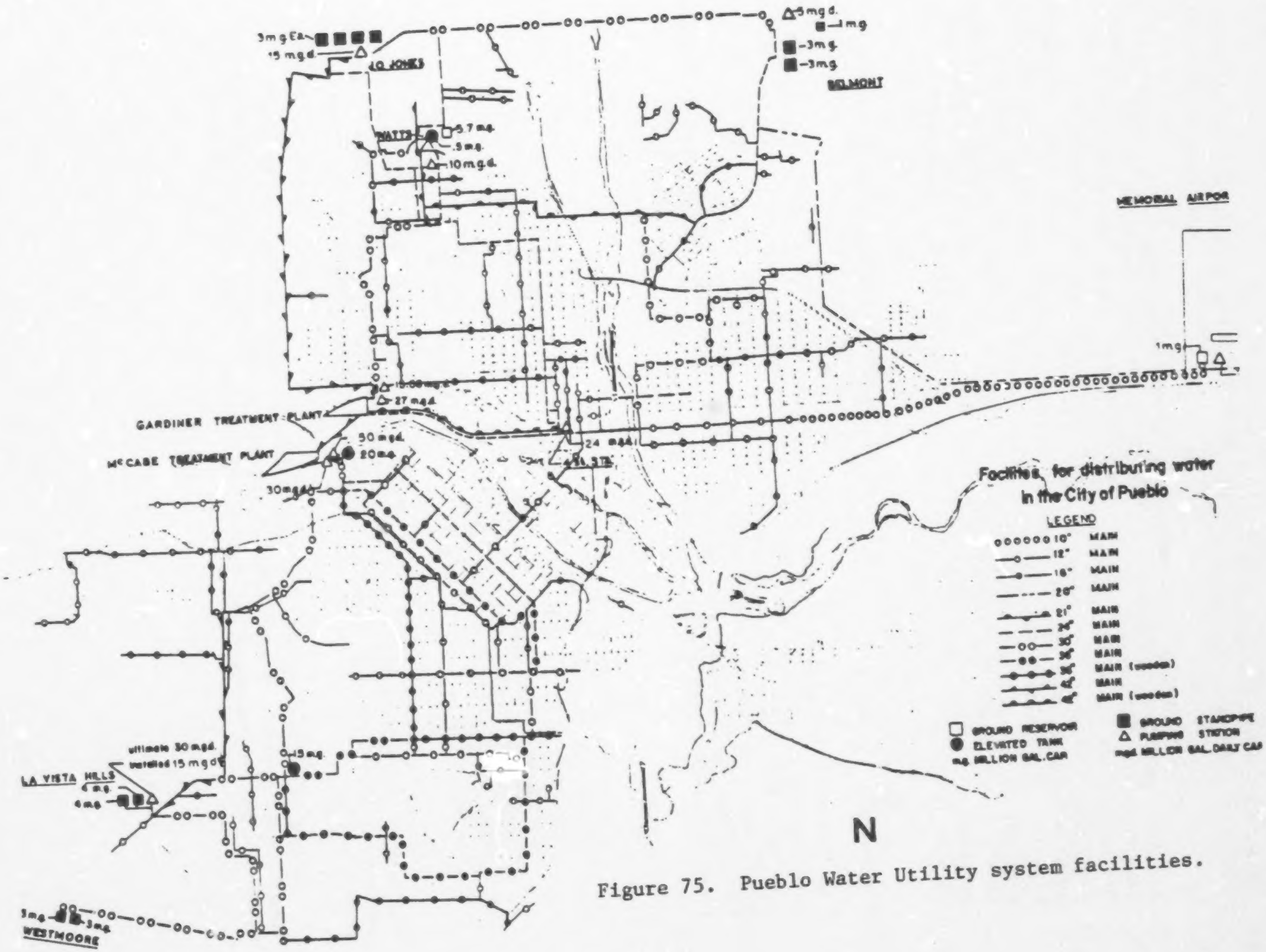

3 mg Ea.
15 mgd.
LO JONES
WATTS
5.7 mg.
.5 mg.
10 mgd.
10.08 mgd.
27 mgd.
5 mgd.
1 mg
3 mg.
3 mg.
BELMONT
MEMORIAL AIRPOR
1 mg
GARDINER TREATMENT PLANT
McCABE TREATMENT PLANT
30 mgd.
20 mg.
30 mgd.
24 mgd.
4th St.
Facilites for distributing water
in the City of Pueblo
LEGEND
10" MAIN
12" MAIN
16" MAIN
20" MAIN
21" MAIN
24" MAIN
30" MAIN
36" MAIN
36" MAIN (wooden)
42" MAIN
42" MAIN (wooden)
GROUND RESERVOIR
ELEVATED TANK
mg. MILLION GAL. CAP.
GROUND STANDPIPE
PUMPING STATION
mgd. MILLION GAL. DAILY CAP.
ultimate 30 mgd.
installed 15 mgd
LA VISTA HILLS
4 mg.
4 mg.
.5 mg.
3 mg.
3 mg.
WESTMOORE
N

Figure 75. Pueblo Water Utility system facilities.

make it possible to aggregate capital and operating cost down to a specific utility; therefore, no schematic diagram is drawn for the Pueblo Water System.

Data were available to establish the operating cost within categories of services provided--acquisition, treatment, pumping, transmitting and distributing water, and general services necessary to support the operation from the standpoint of operations and maintenance and from the standpoint of depreciated capital. To complete the total cost picture, interest also had to be allocated. Because it was difficult to identify specific interest costs with any of the above categories, it was decided to allocate the entire interest amount against all the water produced. By identifying the total cost in the above categories and dividing that total by the amount of RPW, it was possible to identify the unit costs/($/mil gal) for those categories (Figure 76).

In addition these unit costs include depreciated capital allocated to the categories; the cost of interest must also be included.

A linear assumption is made to allow unit cost/($/mil gal) to be added as the water moves from one component of the system to another. Adding the cost of various components, it is possible to determine the average cost/mil gal of water delivered to the customer during the year. Total unit cost is $616.46/mil gal. This figure includes an additional $98.88/mil gal overhead. These data are summarized as follows:

Costs:

Incremental cost ($/mil gal)	$187.77
Distribution cost ($/mil gal)	165.54
Interest cost ($/mil gal)	164.27
Overhead ($/mil gal)	98.88
Total cost ($/mil gal)	616.46
Metered consumption (mil gal)	6,793
Revenue ($)	$4,187,612.78

Once these calculations are made, the cost/mil gal can be compared with the amount charged to the customers for water delivery. Tables 139, 140, and 141 summarize the typical monthly consumption rates charged by the Pueblo Water System.

Table 142 lists the RPW for the 10 largest consumers served by the Pueblo Water System. Examination of the amount billed to the 10 top users shows the Pueblo system is not recovering the cost of the water produced.

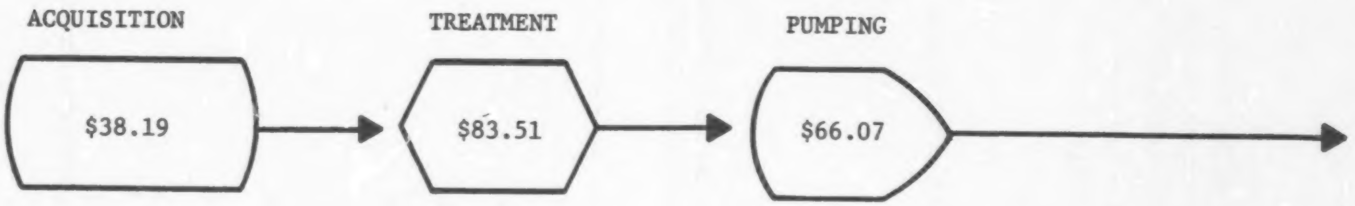

ACQUISITION
$38.19
TREATMENT
$83.51
PUMPING
$66.07

Figure 76. Pueblo Water Utility allocation of capital and operating expenses to water system components ($/mil gal RPW).

TABLE 139. PUEBLO WATER UTILITY WATER RATES, MARCH 1974

	Rate/1,000 gallons	
Monthly usage (gallons)	Inside city	Outside city (Co.)
First 1,000	Minimum charge	Minimum charge
Next 98,000	$0.55	$0.83
Over 100,000	.45	.68

TABLE 140. PUEBLO WATER UTILITY MINIMUM MONTHLY CHARGE BY METER SIZE

Meter size (in.)	Inside city	Outside city (Co.)
5/8	$ 2.96	$ 4.44
1	3.59	5.39
1¼	4.11	6.17
1½	4.68	7.02
2	6.24	9.36
3	13.10	19.65
4	20.90	31.35
6	40.35	60.53
8	59.80	89.70

TABLE 141. RATES FOR MULTIPLE DWELLING UNITS, INSIDE CITY*

Unit	Minimum monthly charges	Next 98,000 gallons	Over 100,000 gallons
First unit	Minimum charge (above)	$0.55	$0.45
Each additional unit	$1.10	.55	.45

* County charges are 1.5 times inside-city charges.

TABLE 142. PUEBLO WATER UTILITY WATER COSTS FOR 10 MAJOR USERS (1974)

Major users	High or low month		Units used (mil gal)	Amount billed*	Unit charge ($/mil gal)	Cost zone
Colorado State Hospital	High	7	33.2	$15,188.34	$457.48	1
	Low	2	11.6	5,235.54	452.28	
C F & I Steel	High	2	32.5	14,130.00	434.82	1
	Low	10	22.9	10,475.77	457.14	
C F & I Steel	High	4	3.5	2,558.98	721.86	1
	Low	10	0.7	542.78	798.21	
Triplex of America	High	8	2.7	1,229.82	584.79	1
	Low	10	2.1	977.37	464.75	
Parkview Episcopal Hospital	High	3	1.5	714.89	473.12	1
	Low	4	0.9	472.79	498.20	
Ramada Inn	High	9	1.6	753.97	465.70	1
	Low	2	0.7	304.75	468.13	
Alpha Beta Packing	High	4	2.5	1,140.40	462.07	1
	Low	9	1.4	658.90	471.32	
M. Occhiato	High	7	1.9	874.90	465.87	1
	Low	1	1.2	542.03	454.34	
Corwin Hospital	High	8	2.4	1,141.40	470.29	1
	Low	6	0.8	419.60	537.26	
Pueblo Golf and Country Club	High	7	16.8	7,631.59	455.59	1
	Low	1	0.3	222.43	724.53	

The average unit costs for all water supplied during the most recent year studied are as follows:

	$/mil gal
Support services	99
Acquisition	38
Treatment	84
Distribution	232
Interest	164
Total	617

SECTION 16

SEATTLE WATER DEPARTMENT

The Seattle Water Department provides water to nine out of 10 residents of King County, Washington. In 1974, the department provided retail service to over 558,000 customers, and through its wholesale customers provided service to an additional 360,000. Population in the service area increased rather rapidly in the 1960's but leveled off during the 1970's, showing a total increase of about 5% over the 10-year period of study. Some system facts are given in Table 143.

WATER SUPPLY SERVICE AREA

The Seattle Water Department provides water on a retail basis to all classes of customers in the City of Seattle and in an area of a few square miles north of the city and some small areas south of the city. In addition, water is wholesaled to other water distributors. Currently, the department provides service to one water district and a portion of the City of Edmonds in Snohomish County. No additional service area is anticipated in Snohomish County. The retail service area encompasses approximately 94 sq miles, and the wholesale area is more than double that size. The service area is shown in Figure 77.

Service is provided to water districts encompassing the more densely populated areas east of Lake Washington. Eventual expansion of service to the east is anticipated to include most of the Snoqualmie River Valley.

The service area is bounded on the south by a line generally extending westerly from the southern boundary of the department's Cedar River watershed. Several communities in the southern portion of the county will continue to be served by the Tacoma Municipal Water System.

Further extension of the service area is anticipated in the future. Therefore, even with a relatively stable population growth, the anticipated expansion will add a significant population to the service area.

ORGANIZATION

The Seattle Water Department utility is a department of the City of Seattle and operates a system for the purpose of supplying water only. The operation is relatively free from other city operations in that it generates its own revenue, including bond issues for capital improvements.

TABLE 143. SEATTLE WATER DEPARTMENT, BASIC FACTS (1974)

Item	Amount
Population:	
SMSA	1,413,307
County	1,146,207
Retail service area	558,200
Size of retail service area (sq miles)	94.5
Recognized customer classes:	
No. of meters	
Residential	152,021
Business	5,193
Commercial	6,022
Government	2,271
Educational and charitable	1,364
Wholesale	150
Purchased water	None
Source water	100% Surface
Pipe in system (miles)	1,547
Elevation of treatment plants (ft above mean sea level):	
Tolt	760
Cedar	540
Elevation of service area (min-max ft)	0-550
Revenue-producing water (mil gal)	45,967
Treated water (mil gal)	55,480
Maximum day/maximum hour (MGD)	300/600

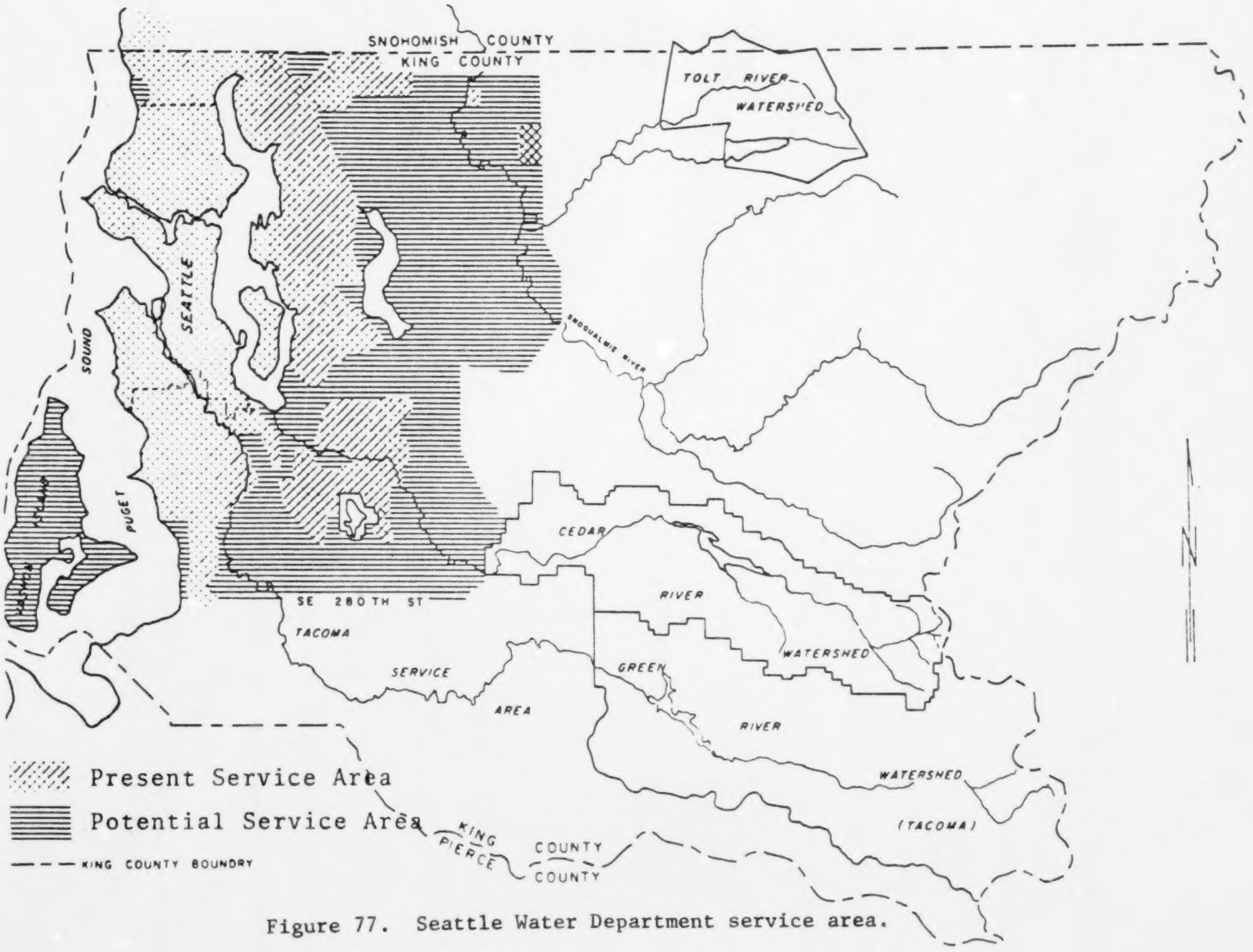

SNOHOMISH COUNTY
KING COUNTY
TOLT RIVER WATERSHED
SEATTLE
SOUND
PUGET
SNOQUALMIE RIVER
CEDAR RIVER WATERSHED
SE 280TH ST
TACOMA SERVICE AREA
GREEN RIVER WATERSHED (TACOMA)
KING COUNTY
PIERCE COUNTY
Present Service Area
Potential Service Area
KING COUNTY BOUNDRY
N

Figure 77. Seattle Water Department service area.

The organization is somewhat different from most city departments in that it is under the City Board of Public Works. The mayor of Seattle appoints the members of the Board of Public Works subject to confirmation by the city council. The Superintendent of Water, one of the five members of the Board, is charged with the operation of the City Water Department.

The Seattle Water Department prepares an annual budget that must be recommended for approval by the mayor and approved by the council. Major construction projects are first submitted to the Board of Public Works which administers the bidding process and the construction contracts for capital improvements. If the cost of the project cannot be defrayed from current revenues, a bond issue is authorized by the council and the Corporation Council prepares a plan or systems ordinance.

As shown in Figure 78, seven divisions report to the Superintendent of Water. Three of these divisions are somewhat different from the usual water organization: Water Resource Management, Office of Management and Planning, and Forestry and Watershed Management. The first two offices show the importance placed on managing the resources and planning ahead to assure that adequate water and service will be available to all areas desiring the service. The Forestry and Watershed Management Division is a function of the source of supply of the Seattle water. All of the raw water from the department comes from watershed areas that are heavily forested and tightly controlled to maintain the quality of the source water.

ACQUISITION

The raw water comes from watersheds located at a considerable distance east of Seattle. The two sources are the Cedar River and the Tolt River.

The area of the Cedar River watershed, approximately 143 sq miles, is forest covered and receives the entire run-off for the Cedar River and its tributaries from an elevation of 540 ft to the summit of the Cascade Mountains, over 6,000 ft in elevation. Precipitation ranges from an annual average of 55 in. at the intake to 110 in. at the headwaters of the river. Almost the entire area is forested with a commercial type forest ranging in age from reproduction to old growth.

The Tolt watershed includes both the north and south forks of the Tolt River and has an area of 40,407 acres, most of which is forest covered.

Both of these watershed areas have a combined ownership by the City of Seattle, private industry (Weyerhauser Company), and the Federal government. The majority of the Cedar River watershed is owned by the City of Seattle, whereas most of the Tolt watershed is owned by private industry. The city and private industry entered into a perpetual agreement to provide the fullest possible use of both the water resources for domestic supply and the land resources for sustained yield lumber products in a comparable manner. In the case of the Cedar River watershed, all access is controlled and unauthorized persons are not allowed entry. No camping or housing facilities are permitted and sanitary provisions are laid down and enforced by the city.

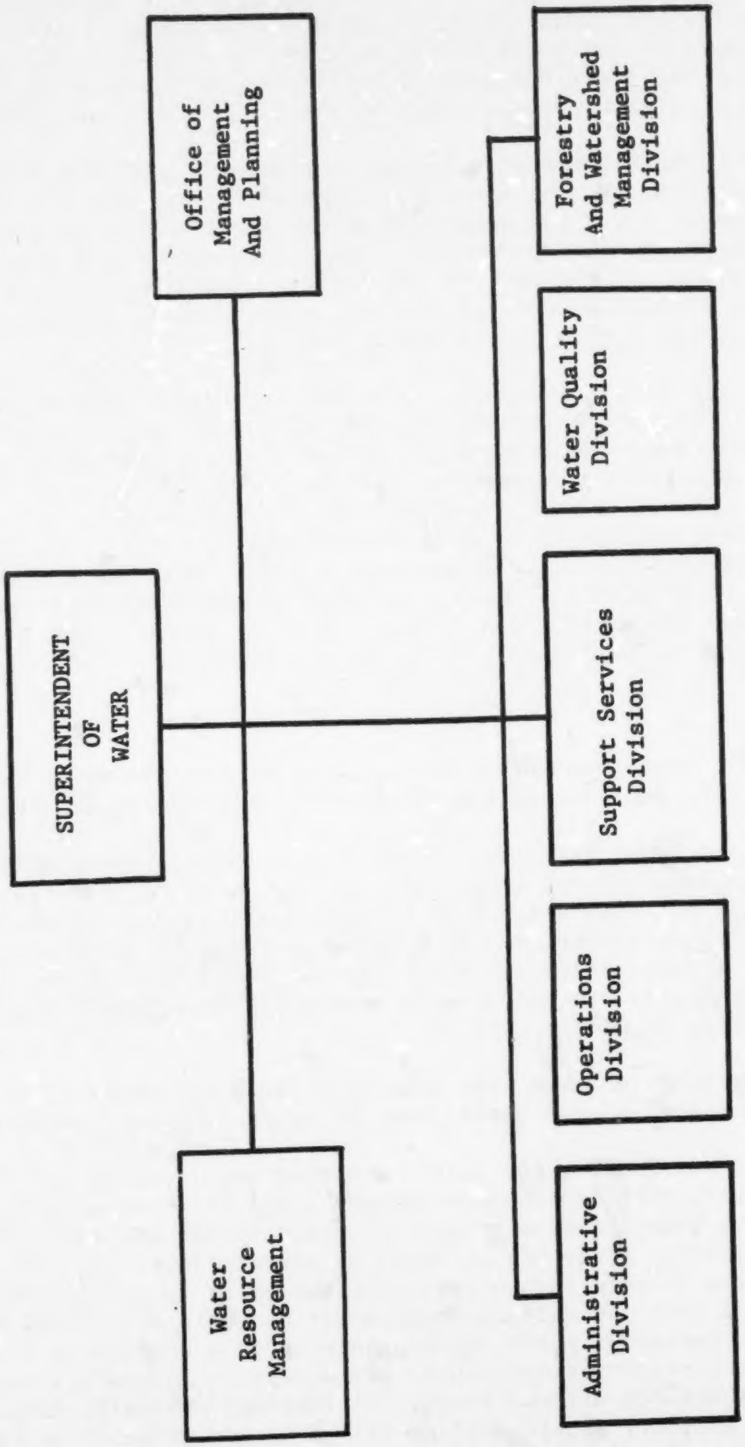

SUPERINTENDENT
OF
WATER
Office of
Management
And Planning
Water
Resource
Management
Administrative
Division
Operations
Division
Support Services
Division
Water Quality
Division
Forestry
And Watershed
Management
Division

Figure 78. Seattle Water Department organizational chart.

Usable storage in impounding reservoirs is maintained in both watershed areas. The Cedar River shed maintains 40,000 acre ft and the Tolt River reservoir maintains 58,000 acre ft. At present, the transmission capacity from the Cedar River area amounts to 240 MGD and the lines from the Tolt River area have a capacity of 100 MGD, providing a total delivery capability of 340 MGD.

TREATMENT

The Seattle Water Department has no specific treatment facility as such and depends heavily on controlling the quality of the source water.

Copper sulfate is added at some of the reservoirs and regulating basins and sodium thiosulphate is added for dechlorination purposes. Sodium hypochlorite is used to disinfect new mains and calcium hypochlorite is used to maintain quality control.

Chlorine and fluoride are added to the water as it leaves the watershed areas and additional chlorine is added at 13 points in the supply system as water is delivered to retail customers. Water delivered to wholesale customers is chlorinated only at the watershed area. Figure 79 shows the points where chlorine and fluoride are added.

TRANSMISSION AND DISTRIBUTION

The transmission and distribution system consists of approximately 1,547 miles of pipe most of which is underground. The general topography of the retail service area is between 0 and 500 ft in elevation. Only small portions of the direct service lie in areas over 500 ft in elevation. There are three levels of pressure zones, generally referred to as low (up to 200 ft), intermediate (200 to 350 ft), and high (350 to 500 ft). Generally, the low and intermediate zones are supplied by gravity and the high service zones are supplied by pumping.

Table 144 shows the capacity and elevation of the system's storage facilities. The storage capability in the distribution system consists of 12 reservoirs, nine standpipes, and eight tanks, providing a total storage of over 445 mil gal. Most of this is in reservoirs. Even during maximum consumption periods, the water system maintains storage at about 84% of total capacity.

COST ANALYSIS

Growth in consumer demand for water from 1965 to 1974 is illustrated in Figure 80. Demand for water increased through 1967 and remained relatively stable from that point on.

Using the standard cost categories, data were collected and reported as shown in Tables 145, 146, and 147. Since a major portion of the operating budget was expended for labor, Table 148 was developed to examine labor costs of the operations and maintenance of the department. The cost/man-hour

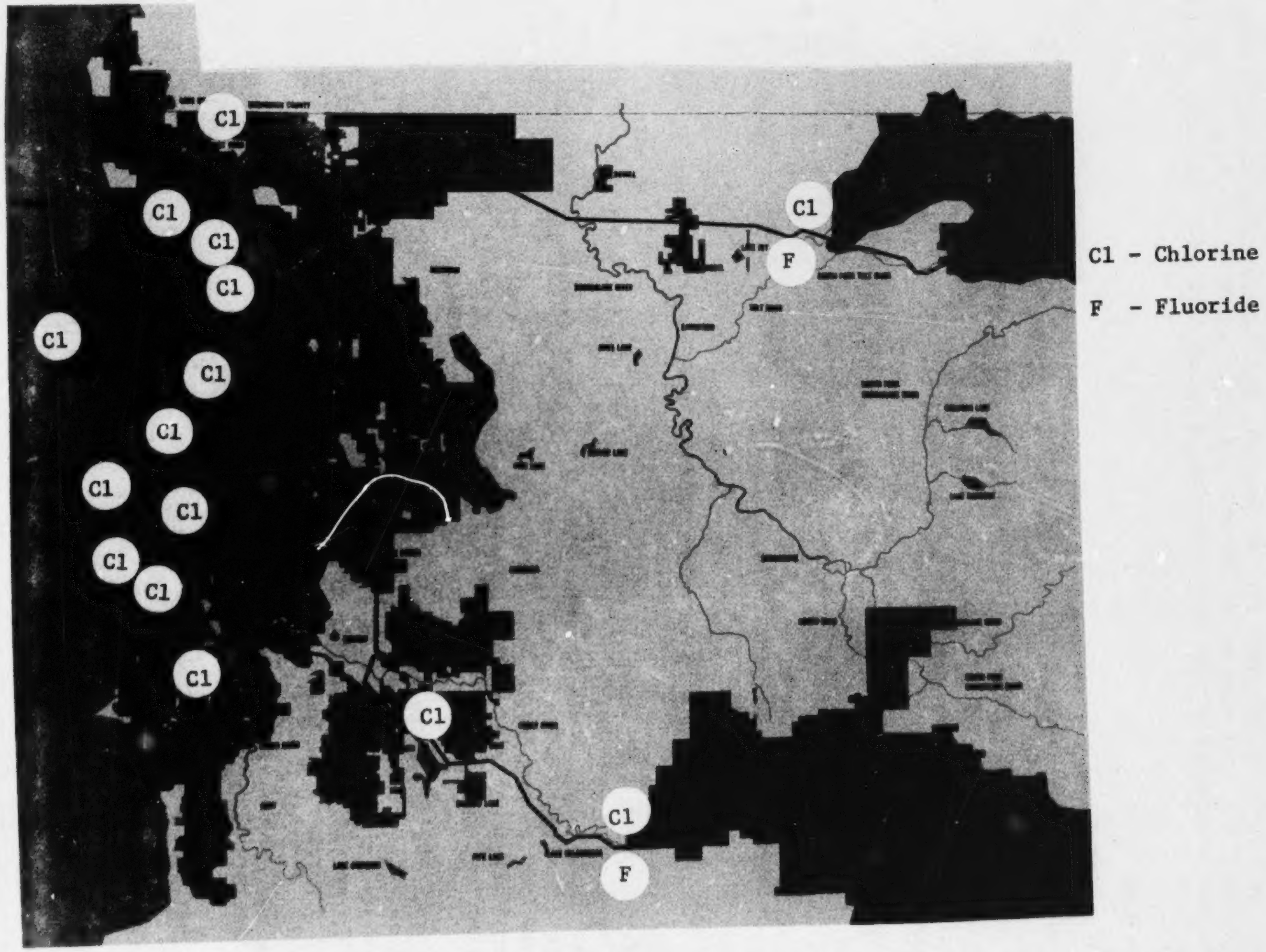

Cl - Chlorine
F - Fluoride
Cl
F
Cl
F
Cl

Figure 79. Seattle Water Department location of system treatment facilities.

TABLE 144. SEATTLE WATER DEPARTMENT STORAGE FACILITIES

Facility	Capacity (mil gal)	Overflow elevation (ft)
Reservoirs:		
Beacon Hill North	61	316
Beacon Hill South	49	316
Bow Lake	6	458
Green Lake	50	316
Lincoln	21	316
Magnolia Manor	5.5	320
Maple Leaf	58.5	420
Volunteer Park	20	420
S.W. Myrtle St.	7	488
West Seattle	68	430
Bitter Lake	21.5	499
Lake Forest	60	540
Standpipes:		
S.W. Barton St.	1.4	316
S.W. Charleston St.	1	488
Foy	1	580
Queen Anne	0.3	520
Queen Ann	0.9	520
S.W. Trenton St.	1.2	320
S.W. Trenton St.	1.2	320
Volunteer Park	0.9	520
Woodland Park	1	420
Tanks:		
Beverly Park	2	575
S. Leo St.	0.5	372
Magnolia Bluff	1	470
Maple Leaf	1	520
Richmond Highlands	1	580
Richmond Highlands	2	580
S.W. Myrtle St.	0.5	575
S.W. Myrtle St.	1	575

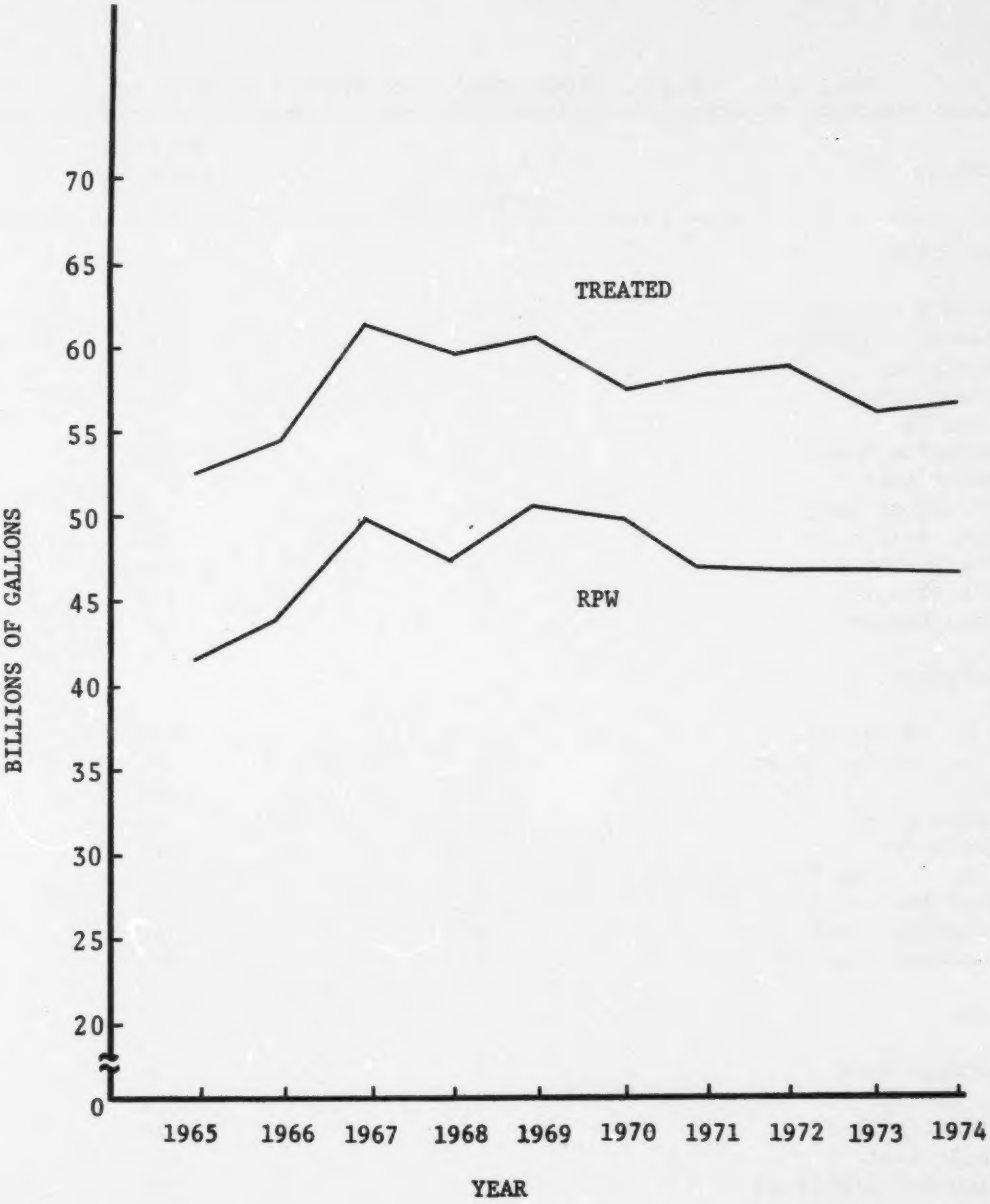


Figure 80. Seattle Water Department water flow: treated water versus RPW.

TABLE 145. SEATTLE WATER DEPARTMENT ANNUAL OPERATING COSTS

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$243,940	$242,601	$227,889	$248,669	$258,719	$255,808	$283,293	$295,206	$348,973	$490,454
Employee pension and benefits	*	*	507,533	561,000	685,341	971,523	1,108,134	1,236,080	1,438,805	1,442,510
Commercial	553,068	544,748	424,285	455,084	473,273	471,345	506,786	568,360	536,445	608,736
Taxes	1,011,909	1,089,770	1,232,892	1,288,440	1,375,555	1,438,671	1,680,017	1,724,002	1,779,936	1,793,864
Miscellaneous undistributed	205,071	202,719	228,383	268,487	275,932	284,768	291,126	335,402	395,690	407,839
Other	49,802	52,122	49,360	55,604	112,823	(67,944)	(17,496)	(15,635)	78,631	67,031
Total support services	2,063,790	2,131,960	2,670,342	2,877,284	3,181,643	3,354,171	3,851,860	4,143,415	4,578,480	4,810,434
Acquisition:										
Acquisition	310,471	319,427	295,447	328,272	465,523	392,376	449,227	455,251	448,903	491,373
Transmission	325,624	283,601	263,828	308,527	275,704	306,710	347,777	402,438	382,544	442,319
Total acquisition	636,095	603,028	559,275	636,799	741,227	699,086	797,004	857,689	831,447	933,692
Treatment:	227,966	266,233	258,862	263,627	329,040	495,615	529,730	539,280	582,333	584,998
Power and pumping:										
Pumping	131,111	121,825	98,145	103,511	123,330	107,125	104,167	132,923	140,004	173,236
Other	27,695	29,551	22,769	23,188	30,521	26,453	25,558	24,004	23,934	21,962
Total power and pumping	158,806	151,375	120,914	126,699	153,851	133,478	129,725	156,927	163,938	195,198
Transmission and distribution:										
Superintendence	121,762	142,630	130,791	156,926	173,144	206,270	206,014	216,770	267,091	488,042
Mains, hydrants, and fountains	388,954	310,777	349,321	386,710	435,888	448,450	537,644	598,318	593,301	572,097
Services	292,325	282,849	263,765	330,491	312,957	400,242	410,595	559,131	524,806	424,704
Meters	200,505	205,005	179,207	207,285	212,954	234,209	257,459	294,110	311,654	304,097
Other	276,089	310,901	285,710	318,888	383,268	431,397	467,297	372,953	354,836	262,906
Total transmission and distr.	1,279,635	1,252,162	1,208,794	1,400,300	1,518,211	1,720,568	1,879,009	2,041,282	2,051,688	2,051,846
Total operating cost	4,366,292	4,404,758	4,818,187	5,304,709	5,923,972	6,403,018	7,187,328	7,738,593	8,207,886	8,576,168

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* Distributed to operating expense accounts.

TABLE 146. SEATTLE WATER DEPARTMENT UNIT OPERATING COSTS ($/mil gal RPW)

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	$6.01	$5.68	$4.67	$5.34	$5.16	$5.15	$6.10	$6.40	$7.61	$10.68
Employee pension and benefits	*	*	10.41	12.04	13.66	19.55	23.87	26.81	31.38	31.42
Commercial	13.62	12.75	8.70	9.77	9.43	9.48	10.92	12.33	11.70	13.26
Taxes	24.91	25.50	25.29	27.66	27.42	28.94	36.18	37.40	38.82	39.08
Misceallaneous undistributed	5.05	4.74	4.68	5.76	5.50	5.73	6.27	7.28	8.63	8.88
Other	1.23	1.22	1.01	1.19	2.25	-1.37	-0.38	-0.34	1.71	1.46
Total support services	50.81	49.89	54.77	61.77	63.42	67.48	82.96	89.88	99.86	104.79
Acquisition:										
Acquisition	7.64	7.48	6.06	7.05	9.28	7.89	9.68	9.88	9.79	10.70
Transmission	8.02	6.64	5.41	6.62	5.50	6.17	7.49	8.73	8.34	9.64
Total acquisition	15.66	14.11	11.47	13.67	14.77	14.06	17.17	18.61	18.13	20.34
Treatment:	5.61	6.23	5.31	5.66	6.56	9.97	11.41	11.70	12.70	12.74
Power and pumping:										
Pumping	3.23	2.85	2.01	2.22	2.46	2.16	2.24	2.88	3.05	3.77
Other	0.68	0.69	0.47	0.50	0.61	0.53	0.55	0.54	0.52	0.48
Total power and pumping	3.91	3.54	2.48	2.72	3.07	2.69	2.79	3.40	3.58	4.25
Transmission and distribution:										
Superintendence	3.00	3.34	2.68	3.37	3.45	4.15	4.44	4.70	5.83	10.63
Mains, hydrants, and fountains	9.58	7.27	7.16	8.30	8.69	9.02	11.58	12.98	12.94	12.46
Services	7.20	6.62	5.41	7.10	6.24	8.05	8.84	12.13	11.45	9.25
Meters	4.94	4.80	3.68	4.45	4.24	4.71	5.55	6.38	6.80	6.62
Other	6.80	7.28	5.86	6.85	7.64	8.68	10.06	8.09	7.74	5.73
Total transmission and distr	31.50	29.30	24.79	30.06	30.26	34.61	40.47	44.28	44.75	44.70
Total operating cost	107.50	103.08	98.82	113.89	118.08	128.82	154.80	167.87	179.02	186.82

* Distributed to operating expense accounts.

The above figures are not additive. They are obtained by dividing yearly mil gal RPW into the annual costs shown in the preceding table.

TABLE 147. SEATTLE WATER DEPARTMENT OPERATING COST CATEGORIES AS PERCENT OF TOTAL OPERATING COST

Category	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Support services:										
Administration	5.59	5.51	4.73	4.68	4.37	4.00	3.94	3.81	4.25	5.72
Employee pension and benefits	*	*	10.53	10.57	11.57	15.18	15.42	15.97	17.53	16.82
Commercial	12.67	12.37	8.81	8.57	7.99	7.36	7.05	7.34	6.54	7.10
Taxes	23.16	24.74	25.59	24.30	23.22	22.46	23.35	22.29	21.67	20.92
Miscellaneous undistributed	4.70	4.60	4.74	5.06	4.66	4.45	4.05	4.33	4.82	4.75
Other	1.14	1.18	1.02	1.05	1.90	-1.06	-0.24	-0.20	0.96	0.78
Total support services	47.26	48.40	55.42	54.23	53.71	52.39	53.57	53.54	55.77	56.09
Acquisition:										
Acquisition	7.11	7.25	6.13	6.19	7.86	6.13	6.25	5.88	5.47	5.73
Transmission	7.46	6.44	5.48	5.82	4.65	4.79	4.84	5.20	4.66	5.16
Total acquisition	14.57	13.69	11.61	12.01	12.51	10.92	11.09	11.08	10.13	10.89
Treatment:	5.22	6.04	5.37	4.97	5.55	7.74	7.37	6.97	7.09	6.82
Power and pumping:										
Pumping	3.01	2.77	2.04	1.95	2.08	1.67	1.47	1.72	1.71	2.02
Other	0.63	0.67	0.47	0.44	0.52	0.41	0.36	0.31	0.29	0.26
Total power and pumping	3.64	3.44	2.51	2.39	2.60	2.08	1.83	2.03	2.00	2.28
Transmission and distribution:										
Superintendence	2.79	3.24	2.71	2.96	2.92	3.22	2.87	2.80	3.26	5.69
Mains, hydrants, and fountains	8.91	7.06	7.26	7.29	7.37	7.01	7.47	7.73	7.24	6.67
Services	6.70	6.42	5.47	6.23	5.28	6.25	5.71	7.23	6.39	4.95
Meters	4.59	4.65	3.72	3.91	3.59	3.65	3.58	3.80	3.80	3.55
Other	6.32	7.06	5.93	6.01	6.47	6.74	6.51	4.82	4.32	3.06
Total transmission and distr	29.31	28.43	25.09	26.40	25.63	26.87	26.14	26.38	25.01	23.92
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

TABLE 148. SEATTLE WATER DEPARTMENT LABOR COST ANALYSIS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total payroll ($)	2,755,495	2,815,573	3,168,326	3,590,589*	4,012,852	4,404,520	4,675,882	4,931,418	5,178,590	5,298,896
Total hours on payroll*	883,353	861,621	899,788	1,018,178	980,137	1,014,563	1,016,644	1,033,079	1,002,604	906,261
Revenue-producing water (mil gal)	40,618	42,731	48,759	46,578	50,169	49,706	46,429	46,099	45,849	45,967
Total pyaroll/mil gal RPW ($)	67.84	65.89	64.98	77.09	79.99	88.61	100.71	106.97	112.95	115.28
Total hours/mil gal RPW	21.75	20.16	18.45	21.86	19.54	20.41	21.90	22.41	21.87	19.72
Average cost/man-hour ($)	3.12	3.27	3.52	3.53	4.09	4.34	4.60	4.77	5.17	5.85

increased over the 10 years by 88% and the total payroll hours required to produce 1 mil gal RPW decreased by approximately 9%. Thus the operating costs for producing water did not increase as rapidly as the labor cost/man-hour. However, when it is no longer possible to gain increased efficiencies with respect to manpower, the payroll cost will increase at least at the same rate as the labor cost.

Table 149 summarizes the operating, depreciation, and interest expenses for the 10-year period of analysis. Table 150 computes capital and operating expenditure ratios. The operating expenses in these tables are those shown as totals of the values in Table 145, expenses incurred in the normal day-to-day operation of the system. Capital expenses are the total expenses for providing major equipment and facilities plus the interest charged on money borrowed for those purposes.

A comparison of operating and capital expenses as a percent of total cost shows that in the Seattle Water Department, greater expense is incurred in operations than in capital outlay. This trend continued over the 10-year period primarily as a result of continued increases in the cost of items necessary to operations, such as increasing salaries. No capital expenditures were made during this period and the ratio of capital to operating expense shifted from 62% operating versus 38% capital to 71% operating versus 29% capital.

The Seattle Water Department's system is relatively old; therefore, the capital depreciated was expended when costs were significantly lower than at present. On the other hand, the operating expense is in current dollars. This ratio will increase as capital investments are made by the utility. For example, major capital expense may be required in the future to expand the source of water supply or additional treatment facilities may be needed to meet the requirements of the Safe Drinking Water Act. Should either of these eventualities occur, the ratio of capital to operating expense will increase significantly.

SYSTEM COSTS

Examination of costs on a functional basis is only a part of the total picture. Because the purpose of a water supply utility is to deliver water to the customers, it is important to be able to present costs as they relate water delivery to a demand point in the distribution system. For this reason, the functional categories, both operating and capital, are reaggregated and assigned to physical components in the water delivery system. This section contains such an analysis.

Locations of the service area and the watersheds in the mountains to the east of the service area are shown in Figure 81. Because the watersheds provide water primarily by gravity to the northern extremity of the distribution system and on toward the middle of the service area, there is little incremental cost for providing water to the distribution system other than the differences in the cost of the sources and in moving the water from the source to the distribution system.

TABLE 149. SEATTLE WATER DEPARTMENT CAPITAL AND OPERATING COSTS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense	$4,366,292	$4,404,758	$4,818,187	$5,304,709	$5,923,972	$6,403,018	$7,187,328	$7,738,593	$8,207,886	$8,576,168
Depreciation	1,761,320	1,819,344	1,858,194	1,883,228	1,924,747	1,995,275	2,064,071	2,122,696	2,236,003	2,285,054
Interest	954,300	942,601	927,385	977,691	1,082,324	1,051,397	1,046,567	1,187,107	1,266,572	1,234,900
Total	7,082,412	7,166,703	7,603,166	8,165,628	8,931,043	9,449,690	10,297,966	11,048,396	11,709,466	12,096,122
Total cost/mil gal RPW	174.37	167.71	155.95	175.31	178.02	190.11	221.80	239.67	255.39	263.15

TABLE 150. SEATTLE WATER DEPARTMENT CAPITAL VERSUS OPERATING EXPENSE RATIOS

Item	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
Operating expense ($)	4,366,292	4,404,758	4,818,187	5,304.709	5,923,972	6,403,018	7.187,328	7,738,593	8,207,886	8,576,168
Capital expense ($)	2,716,120	2,761,945	2,784,979	2,860,919	3,007,071	3,046,672	3,110,638	3,309,803	3,501,580	3,519,954
Total ($)	7,082,412	7,166,703	7,603,166	8,165,628	8,931,043	9,449,690	10,297,966	11,048,396	11,709,466	12,096,122
Operating expense as % of total	61.65	61.46	63.37	64.96	66.33	67.76	69.79	70.04	70.10	70.90
Capital expense as % of total	38.35	38.54	36.63	35.04	33.67	32.24	30.21	29.96	29.90	29.10

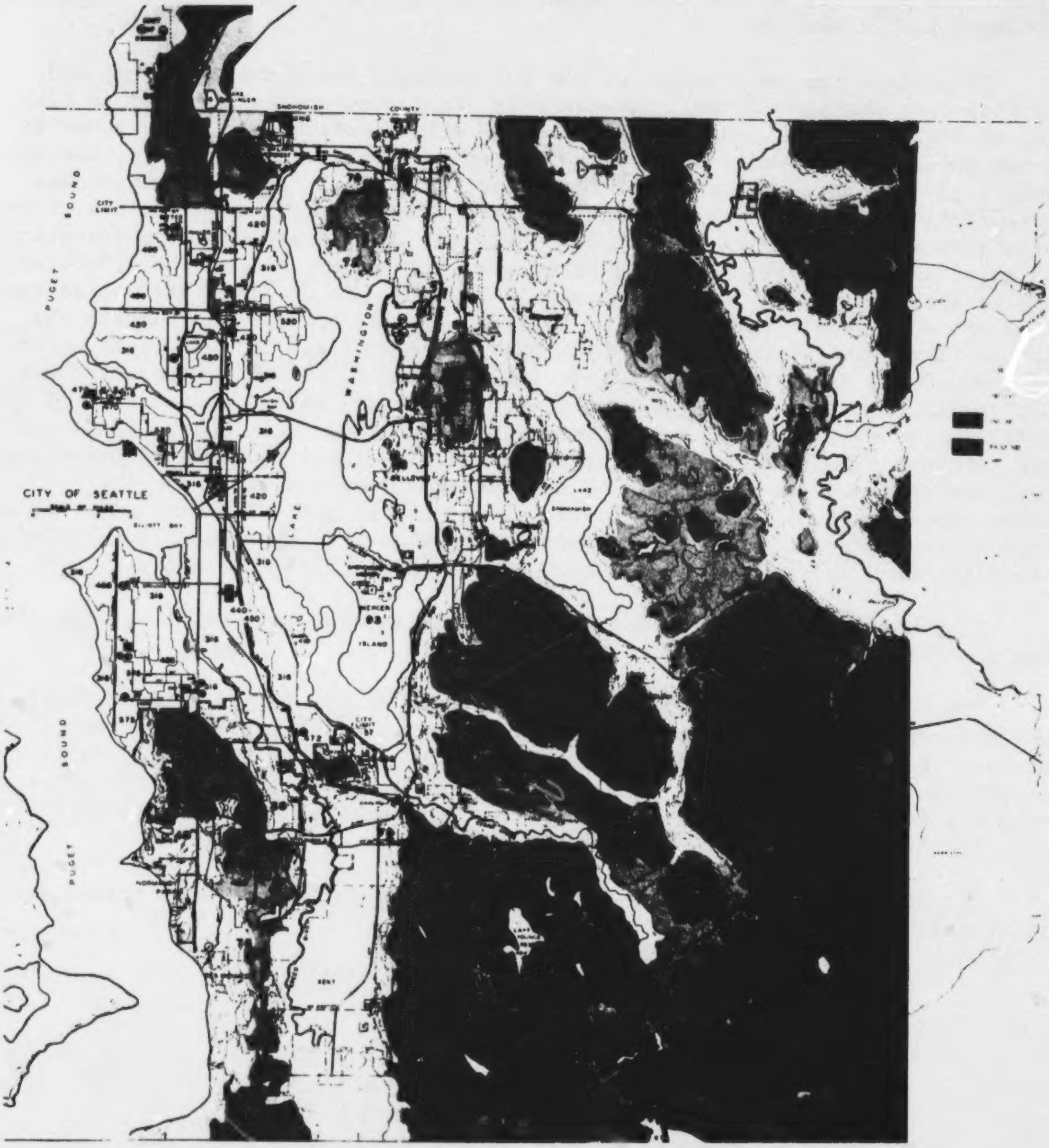
SNOHOMISH COUNTY
CITY LIGHT
PUGET SOUND
WASHINGTON
LAKE
CITY OF SEATTLE
ELLIOTT BAY
MERCER ISLAND
LAKE SAMMAMISH
CITY LIGHT
PUGET SOUND
KENT

Figure 81. Seattle Water Department distribution area.

Figure 82 shows the allocation of operating and capital costs to the various components of the Seattle system. Because the major cost variation is based on the specific source of the water, the cost of the delivered water is associated with the source rather than any specific point or pressure zone of delivery to the customer.

To analyze the cost impact of the two sources, the total operating and capital cost for each of the components is identified and established in $/mil gal of RPW. A linear assumption is made to allow cost/mil gal to be added as water moves from one component of the system to another. For example, the acquisition cost at the Cedar River watershed is $3.78/mil gal. An additional $29.87/mil gal is added to transmit the water from the source to the distribution system. A treatment cost of $4.50/mil gal is incurred with the insertion of chlorine and fluoride into the water near the source, and another $5.70/mil gal is incurred in adding chlorine and other chemicals in the distribution system. An additional average cost of $5.06/mil gal is incurred in pumping the water. The total incremental cost is thus $48.91/mil gal for providing water from the Cedar River watershed (Table 151). Added to these incremental costs are the distribution, interest, and support services costs. Calculation of the distribution cost is based on the assumption that these unit costs ($/mil gal) are constant throughout the system; therefore, the total capital and operating cost for distribution is divided by the number of gallons of RPW in the year under consideration, yielding a figure of $72.16/mil gal. The same approach is used to calculate interest and support services costs. When these are added, the total cost of water from the Cedar River source is $257.05/mil gal.

Tables 152, 153, and 154 summarize typical monthly water rates charged by the Seattle Water Department.

Table 155 shows the cost of water delivered to the 10 largest customers of the department. Comparing each user's location with the cost allocation table makes it possible to identify the actual allocated cost of delivering water to a specific customer. Locations of major users are shown in Figure 83. Most of them are in the central or southern portion of the service area, predominantly supplied by the Cedar River watershed.

The average unit costs for all water supplied during the most recent year studied are given as follows:

	$/mil gal
Support Services	109
Acquisition	37
Treatment	13
Distribution	77
Interest	27
Total	263

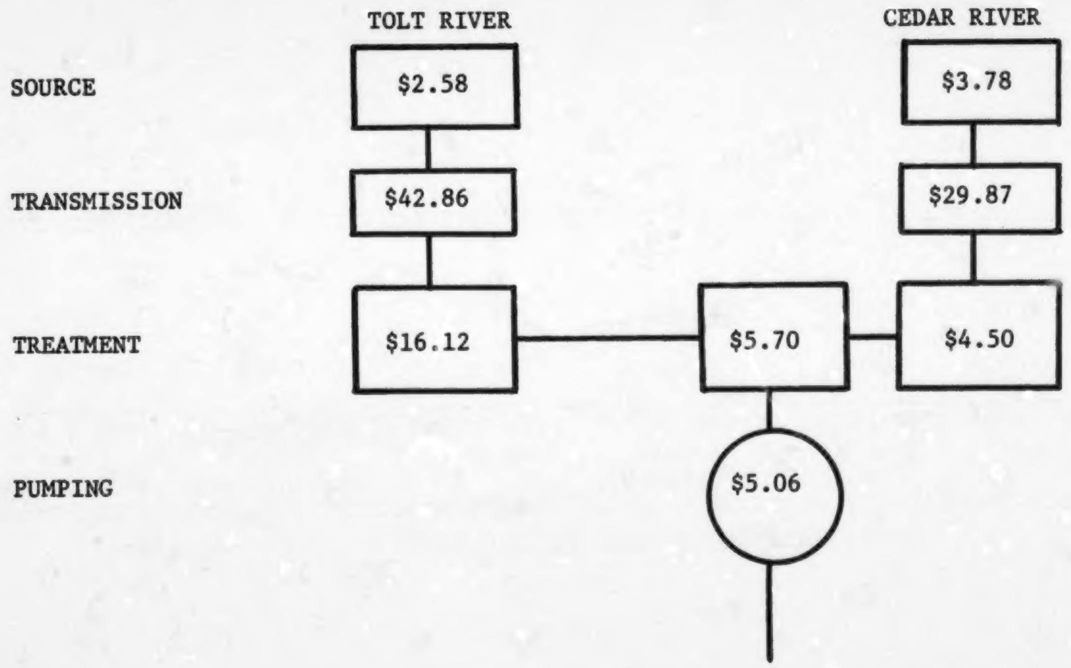
TOLT RIVER
CEDAR RIVER
SOURCE
TRANSMISSION
TREATMENT
PUMPING
$2.58
$42.86
$16.12
$3.78
$29.87
$4.50
$5.70
$5.06

Figure 82. Seattle Water Utility allocation of capital and operating expenses to system components ($/mil gal RPW).

TABLE 151. SEATTLE WATER UTILITY COST ELEMENTS BY SOURCE

Water Source	Incremental cost ($/mil gal)	Distribution cost ($/mil gal)	Interest ($/mil gal)	General Services ($/mil gal)	Total unit cost ($/mil gal)	RPW (mil gal)	Revenue
Tolt River	72.32	72.16	26.86	109.12	280.46	11,967	3,356,265
Cedar River	48.91	72.16	26.86	109.12	257.05	34,000	8,739,700
Total	---	---	---	---	---	45,967	12,095,965

TABLE 152. SEATTLE WATER DEPARTMENT MINIMUM CHARGE BY METER SIZE INSIDE CITY LIMITS

Meter size (in.)	Monthly volume base (cu ft)	Minimum charge
3/4	300	$ 2.10
1	600	2.80
1½	1,200	4.10
2	2,000	5.80
3	3,400	8.70
4	4,900	12.00
6	7,100	16.50
8	10,000	23.00
10	14,000	31.50
12	20,000	44.00

TABLE 153. SEATTLE WATER DEPARTMENT MINIMUM CHARGE BY METER SIZE OUTSIDE CITY LIMITS*

Meter Size (in.)	Monthly volume base (cu ft)	Minimum charge
3/4	300	$ 3.15
1	600	4.20
1½	1,200	6.15
2	2,000	8.70
3	3,400	13.05
4	4,900	18.00
6	7,100	24.75
8	10,000	34.50
10	14,000	47.25
12	20,000	66.00

* Other than water districts or cities.

TABLE 154. SEATTLE WATER RATES FOR ALL METER SIZES

Use level	Rate
Inside city limits:	
Each 100 cu ft over your volume base, to 30,000 cu ft	$0.213
Each 100 cu ft after 30,000 cu ft	.142
Each separate building or premises supplied through the same connection (except trailer parks), minimum charge for 500 cu ft, volume base	2.50
Outside city limits:	
Each 100 cu ft over your volume base, to 30,000 cu ft	.32
Each 100 cu ft after 30,000	.213
Each separate building or premises supplied through the same connection (except trailer parks), minimum charge for 500 cu ft, volume base	3.75

TABLE 155. SEATTLE WATER DEPARTMENT WATER COSTS FOR 10 MAJOR USERS

Major users	High or low month	Month	Units used (mil gal)	Amount billed	Unit charge ($/mil gal)	Cost zone
Boeing	High	10	121.3	$19,606	$161.64	2
	Low	12	89.6	14,260	159.16	
University of Washington	High	11	64.5	8,702	134.93	1
	Low	2	42.5	5,768	135.56	
Port of Seattle	High	2	53.1	7,396	139.29	2
	Low	5	36.8	5,135	139.64	
Bethlehem	High	6	38.8	5,231	134.92	2
	Low	12	26.2	3,547	135.51	
Todd Shipyards	High	7	34.6	4,660	134.61	2
	Low	1	15.9	2,368	148.65	
Sicks Ranier	High	7	32.0	4,349	135.71	2
	Low	2	15.9	2,193	137.78	
Northwestern Glass	High	8	21.1	2,868	135.94	2
	Low	5	14.2	1,947	137.09	
E.M. Jorgensen	High	2	28.0	5,684	203.23	2
	Low	4	3.9	852	220.00	
Seattle Steam Corporation	High	1	26.2	1,466	55.90	2
	Low	9	7.1	981	138.29	
Monsanto	High	10	22.7	4,610	201.63	2
	Low	5	9.9	2,010	203.20	

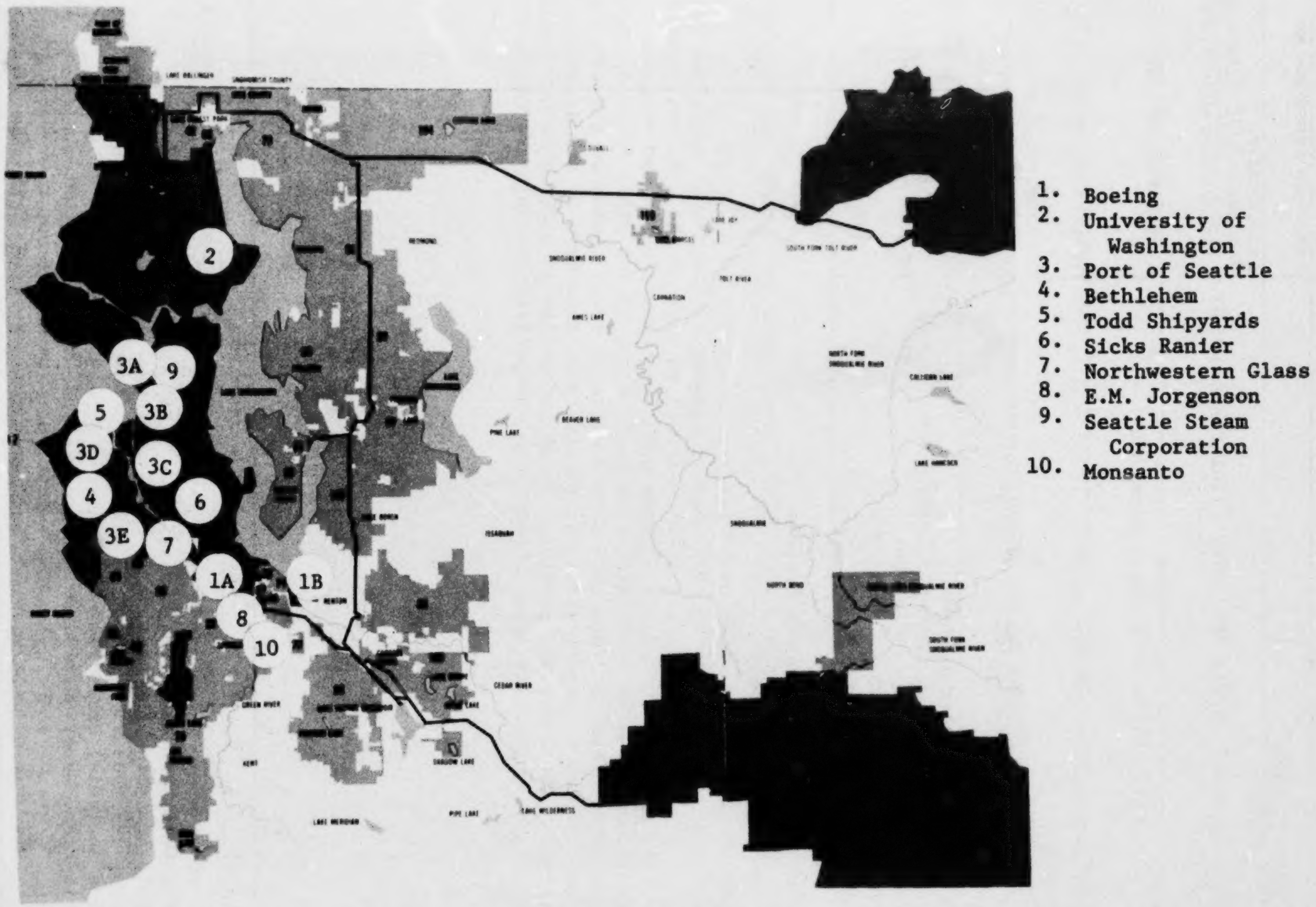
2
3A
9
5
3B
3D
3C
4
6
3E
7
1A
1B
8
10
REDMOND
CARNATION
ISSAQUAH
SNOQUALMIE
NORTH BEND
CEDAR RIVER
GREEN RIVER
KENT
1. Boeing
2. University of Washington
3. Port of Seattle
4. Bethlehem
5. Todd Shipyards
6. Sicks Ranier
7. Northwestern Glass
8. E.M. Jorgenson
9. Seattle Steam Corporation
10. Monsanto

Figure 83. Locations of Seattle Water Department major users.